DOCUMENT RESUME

ED 121 013 95 EC 082 522

AUTHOR Weber, Donald B.
TITLE Primacy and Recency Effects for Serially Presented Supraspan Information in Normal and Learning Disabled Children. Final Report.
INSTITUTION Pennsylvania State Univ., University Park.
SPONS AGENCY Bureau of Education for the Handicapped (DHEW/OE), Washington, D.C.
REPORT NO HO111SJ
PUB DATE Sep 75
GRANT OEG-0-74-7457
NOTE 150p.

EDRS PRICE MF-$0.83 HC-$7.35 Plus Postage
DESCRIPTORS Auditory Perception; Elementary Education; Exceptional Child Research; *Learning Disabilities; *Learning Modalities; *Learning Processes; *Memory; Visual Perception

ABSTRACT

Primacy and recency aspects of short term memory (STM) were investigated with 30 learning disabled (LD) and 30 normal children, all with a mean age of 113 months. The pretest experiment compared the serial position curve performance of LD and normal children when seven-digit series were presented visually or auditorially. The second experiment compared the effects of training encoding processes in the LD children who received 8.7 hours of training in one of three treatments--chunking (organizing serial input into units), verbal stringing (repeating orally the entire series as each new element is added), and hawthorne (a control treatment). It was concluded that the overall performances of LD children in STM were qualitatively similar to but quantitatively lower than normal children, while secondary memory for LD children was disproportionately more inefficient than primary memory. The training of rehearsal strategies did not produce a significant differential improvement in primacy performance, though chunking appeared to be a more effective strategy when used to organize visual stimuli (when presented slowly) and verbal stringing a more effective strategy for rehearsal of auditory stimuli. (Author/DB)

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Final Report

Project No. H0111SJ
Grant No. OEG-0-74-7457

Primacy and Recency Effects for Serially Presented Supraspan Information in Normal and Learning Disabled Children

Donald B. Weber
The Pennsylvania State University

September 1975

Department of Health, Education, and Welfare

U. S. Office of Education
Bureau of Education for the Handicapped

EC084582

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ABSTRACT

Thirty Ss were children enrolled in classes for learning disabled children. Their chronological ages ranged from 81 to 136 months with a mean age of 113.4 months. Thirty Ss enrolled in regular classrooms were matched by chronological age with the learning disabled Ss. Their chronological ages ranged from 85 months to 134 months with a mean age of 113.37 months.

There were two phases in the study. The pretest experiment compared the serial position curve (SPC) performance between learning disabled children and normal children across two modalities with two different presentation rates (one- and two-second inter-item intervals). The experiment consisted of a seven-digit series presented visually at one- and two-second rates (54 trials) and auditorily at one- and two-second rates (54 trials).

The second experiment compared the effects of training encoding processes in learning disabled children. The learning disabled children were stratified into blocks of three subjects on the basis of the pretest scores and randomly assigned to one of three treatments (chunking, verbal stringing, and hawthorne). The entire treatment phase consisted of three half-hour sessions per week for a period of six weeks. The mean number of actual hours for each treatment group was slightly less than nine hours: (1) chunking group's mean time equalled 8.65 hours; (2) verbal stringing group's mean time equalled 8.72 hours, and (3) hawthorne group's mean time equalled 8.72 hours. Posttests were administered to the learning disabled subjects upon completion of the treatment. The four recall conditions that were employed during the

pretest stage were maintained. New randomizations of seven-digit series were generated for the posttests.

It was concluded that the overall performances of learning disabled children in STM were qualitatively similar to but quantitatively lower than normal children. Secondary memory for learning disabled children was disproportionately more inefficient than primary memory with respect to normal children.

The training of rehearsal strategies did not produce a significant differential improvement in primacy performance. It was concluded that practice with some strategy keeps the subject using a strategy during longer intervals of presentation. Chunking appeared to be a more effective strategy when used to organize slower presented visual stimuli whereas verbal stringing appeared to be more effective for rehearsal of auditory stimuli during both the one- and two-second rates.

Chapter I

INTRODUCTION

With the introduction of the study of learning disabilities during the 1960s, a new category of exceptionality was delineated. Extensive interest in this area has resulted in a growth rate unparalleled "by any other discipline within special education" (Hallahan & Cruckshank, 1973). Although the term learning disabilities was nonexistent prior to this period, terms such as perceptual handicap, brain injury, minimal brain dysfunction, etc., were interchangeably used to describe children exhibiting specific types of behavioral aberrations. The category learning disabilities (Kirk, 1963) was proposed as an attempt to establish a common nomenclature encompassing a broad spectrum of behavioral anomalies.

The criteria for definitive differentiation of learning disabilities from other exceptionalities have remained unresolved (Johnson, 1975; Vaughn & Hodges, 1973). Myklebust's suggested criteria (1964) of general integrity and a deficiency in learning as a minimum requirement for learning disabilities have generally been incorporated in the most widely accepted definitions (Bateman, 1965; Clements, 1966; National Advisory Committee for the Handicapped, 1968). These definitions reflect an inherent difficulty in delineating a homogeneous population of learning disabled children.

There is agreement among educators and psychologists that there are "intellectually normal" children who exhibit a pronounced disparity

between predicted and observed achievement. There is, however, no consensus regarding the causative factors of learning disabilities and therefore the optimal remediation to be employed. An extensive effort in research has been directed toward the identification and refinement of knowledge concerning the learning characteristics of the learning disabled.

An important component in learning is memory. Melton (1963) has described the memory domain of learning as "concerned with storage and retrieval of the residues of demonstrable instances of association formation." Several contemporary researchers (Atkinson & Shiffrin, 1968; Ellis, 1970; Waugh & Norman, 1965) have postulated a multi-process memory model composed of three separate storage systems: a sensory register (SR), a short-term memory (STM), and a long-term memory (LTM). The empirical evidence supporting the existence of SR has been widely accepted (Neisser, 1970). Kintch (1970) has presented substantial evidence to support the distinction between STM and LTM as separate storage systems. A primary distinction between STM and LTM has been the durability of storage. Atkinson and Shiffrin (1968) have defined STM as a working memory. Whereas LTM has generally been considered as a permanent store of information (Penfield, 1959).

The importance of short-term memory in complex cognitive processes has been recognized by several researchers (Guilford, 1962; Miller, 1956; Simon, 1974).

> A crucial role in problem-solving is played by man's short-term memory and the processes that transfer information from short-term to long-term memory (fixation processes). To continue the progress toward understanding complex cognitive behaviors, it is necessary to have good estimates of the basic parameters of short-term memory and of the memory fixation process. (Simon, 1974, p. 482)

Guilford (1962) has suggested the importance of short-term memory as a factor aiding creativity. The facility to retain information in STM would appear to be a critical skill in problem-solving situations.

There has been evidence to indicate that STM is closely related to intelligence. Jensen (1964) found that the digit span subtest of the Wechsler Adult Intelligence Scale (WAIS) correlated highly with other subtests after correction for attenuation. Miller (1956) has succinctly stated this relationship,

> From the first it was obvious that this span of immediate memory was intimately related to general intelligence. Jacobs reported that the span increased between the ages of 8 and 19, and his test was later incorporated by Alfred Binet, and is still used, in the Binet Intelligence Test. (1956, p. 4)

Jacob's evidence that STM shows developmental changes has been supported in other studies (Flavell, Beach & Chinsky, 1966; Hagen & Kingsley, 1968).

There has been substantial evidence to indicate that STM is comprised of two memory processes (Ellis & Hope, 1968; Glanzer & Cunitz, 1966; Moss & Sharae, 1970). The dual-process in STM has been demonstrated by the manifestation of a primacy and recency effect in the recall of serially presented stimuli. The primacy performance is considered to reflect the use of mediation or rehearsal strategies to retain input. Whereas the recency performance is considered dependent on immediate memory or the sensory register; both processes are employed to organize and retain stimuli in STM tasks.

It has been suggested by several authors that learning disabled (LD) children exhibit an inability to organize and hold stimuli in memory (Birch, 1964; Johnson & Myklebust, 1967; Strauss, 1941). These authors have inferred a perceptual disorder to account for this memory

deficiency. However, systematic application of a dual process STM model to interpret LD primacy-recency performance might reveal that this deficiency is a result of an inefficient rehearsal strategy rather then an aberration in perceptual processes.

The demonstration of a rehearsal strategy deficiency for LD children would have definite educational implications. Research evidence has indicated the feasibility of training more effective rehearsal strategies (Belmont & Butterfield, 1971; Kellas, Ashcraft, & Johnson, 1973). Therefore, the effect such training would have on the STM performance of LD children warrants investigation.

Chapter II

REVIEW OF THE LITERATURE

This chapter contains a discussion of the literature pertinent to this study and a statement of the problem to be investigated. The review of the literature will be considered in separate sections. Studies dealing with STM in learning disabled children will be discussed in the first section. A theoretical model for STM and applied studies in STM will be included in the second section. Studies concerning the experimental use of encoding processes will be considered in the third section. The statement of the problem will include a discussion of the hypotheses to be investigated in this study.

Short-Term Memory in Learning Disabled Children

Several studies have investigated STM performance in learning disabled children. Senf and Freundl (1972) presented progressively more difficult series of digits, i.e., three-digits through six-digits, to subjects with a mean chronological age (CA) of 9 years and 4 months. Visual and auditory stimuli were randomly given to each subject. They found that the learning disabled children exhibited deficiencies in both modalities. Greater gross errors and order errors were evident as the digit span increased. The authors advanced an attentional deficit hypothesis to account for their results.

In another study, Senf and Freundl (1971) used a dichotic listening procedure to study STM. By means of an audiovisual analogue, three pairs of words were simultaneously presented to the subjects. They found that when asked to recall the pairs, the younger learning disabled subjects (mean CA 9 years 5 months) demonstrated no deficiency. However, when instructed to recall by modality, the learning disabled subjects were less capable of remembering under this condition. For the older subjects, (mean CA 14 years 6 months) just the opposite occurred. Bryson (1972) in a study with young autistic children had similar results.

Fenton, Alley, and Smith (1974) investigated the effects of white noise on the STM performance of learning disabled children. Five levels of white noise were introduced while the subjects repeated 4-digit numbers. They found no significant difference in performance between the normal and learning disabled subjects.

A few studies have investigated the relationship between visual sequential memory and reading ability. Kass (1966) administered a number of specific ability tests to reading disabled children within the age range of 7 years to 9 years and 11 months. She found that reading disabled children exhibited deficiencies in the auditory-vocal association, auditory-vocal automatic, auditory sequencing, visual sequencing, visual automatic, and sound blending subtests of the Experimental Illinois Test of Psycholinguistic Abilities (ITPA). The reading disabled children did not exhibit a deficiency on the auditory decoding and auditory-vocal subtests of the same measure.

Carroll (1972) attempted to investigate the relationship between short-term memory and different behavioral characteristics in three

different groups of 5 to 6 year old children. The groups were composed of normal children, educable mentally retarded children, and educable mentally retarded children with central nervous system (CNS) impairment. He found a significant negative correlation between memory errors and tests of reading readiness achievement. Of particular interest was the fact that his Visual Memory Scale (VMS) differentiated between the groups of neurologically impaired retarded children and non-neurologically impaired children.

Guthrie and Goldberg (1972) found a significant positive relationship between visual sequential memory and paragraph comprehension, oral reading, and word recognition. Noelker and Shumsky (1973) found that reading disabled children, when compared to superior readers, demonstrated more position errors. Short-term memory has generally been found to have a positive correlation with reading achievement.

Recent interest has been generated in the study of aptitude-treatment interaction (ATI) and its application to learning disabled children. An area of interest to researchers has been the study of modality preferences in learning as they relate to instructional strategies and materials. Short-term memory measures have been used to identify visual and auditory learners.

Bateman (1968) attempted to investigate the efficacy of preferred modality instruction of reading to first grade children. She identified children as "visiles" or "audiles" on the basis of their performance on the ITPA auditory sequential memory subtest and the visual sequential memory subtest. She classified children as audiles if auditory memory scores exceeded visual memory scores by at least nine months. Children whose visual memory scores exceeded auditory

scores, but not by the nine months, were considered visiles. Reading instruction was then given to the audiles and visiles in their preferred modality. She was unable to find a significant aptitude-treatment interaction. Ysseldyke (1973) has questioned the methodological procedures employed in this study.

Lilly and Kelleher (1973) attempted to apply more reliable measures to the identification of visual and auditory learners. They devised a STM test which consisted of twenty words in the immediate sight vocabulary of each child to be tested. The test required the child to recall the stimuli in the same order that it was presented. The stimuli for both the visual and auditory tasks were presented for 10 seconds. The number of words in the stimuli increased by one if the child responded correctly. The testing was terminated when the child gave the incorrect response for two consecutive trials. The audiles and visiles were identified by the difference between visual and auditory scores in relation to the grand mean performance for both modalities. The audiles and visiles were then compared on a memory task for written and oral stories. The analysis indicated a significant aptitude-treatment interaction between modality preference and stimuli presentation.

The evidence to support a modality-by-treatment interaction has been inconclusive. The validity of employing STM measures to identify audiles and visiles has not been substantially proven. Some authors have contended that the recoding processes employed in STM are independent of the presentation mode (Neisser, 1970; Sperling, 1967).

A few authors have attempted to investigate the effect of mediation strategies with learning disabled children. Bryan (1972) employed a task which forced the learning disabled children to use

specific mediation strategies in STM. She found that the learning disabled children performed significantly lower than the normal control group. Freston and Drew (1974) studied the effect of external organization of stimuli on the recall performance of learning disabled children. Stimuli were prearranged according to associative value, i.e., items from a common category such as food. They found that the external organization of stimuli had no effect on the recall performance.

Theoretical Model

Numerous models of human memory have been proposed to describe the processes involved in memory (Cermak, 1972). The purpose of such models is to provide a framework within which the research data may be interpreted. For the purposes of this study, Ellis's Multi-Process Memory Model (1970) has been selected.

Ellis (1963) had originally proposed a Stimulus Trace Theory to account for an inadequate STM in intellectually subnormal children. He hypothesized that the strength and duration of the stimulus trace was a function of both age and intelligence. However, Ellis and Hope (1968) performed a series of experiments which seemed to yield results supporting a multi-process memory theory. By altering the rates of presentation, they found differential effects in the primacy and recency segments of a serial position curve (SPC) (Figure 1). Primacy seemed to be directly related to the presentation rate and recency exhibited no substantial effect. In order to account for these results, Ellis (1970) generated a multi-process memory model to describe the memory operations. Figure 2 represents a graphic illustration of the two processes in STM delineated by Ellis.

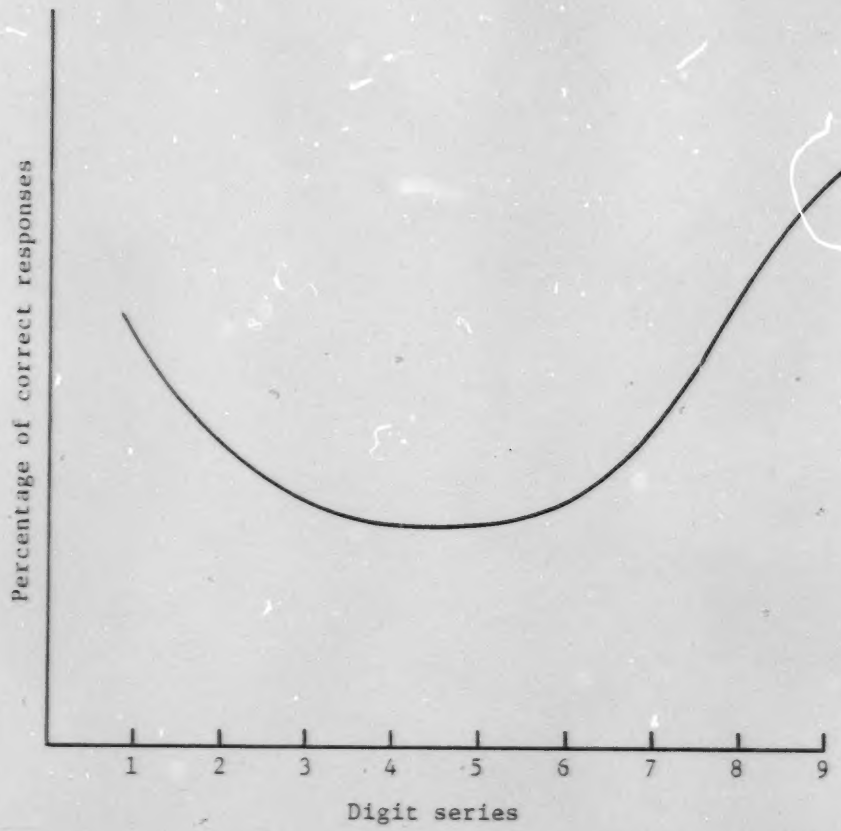

Figure 1. Primacy and recency effect

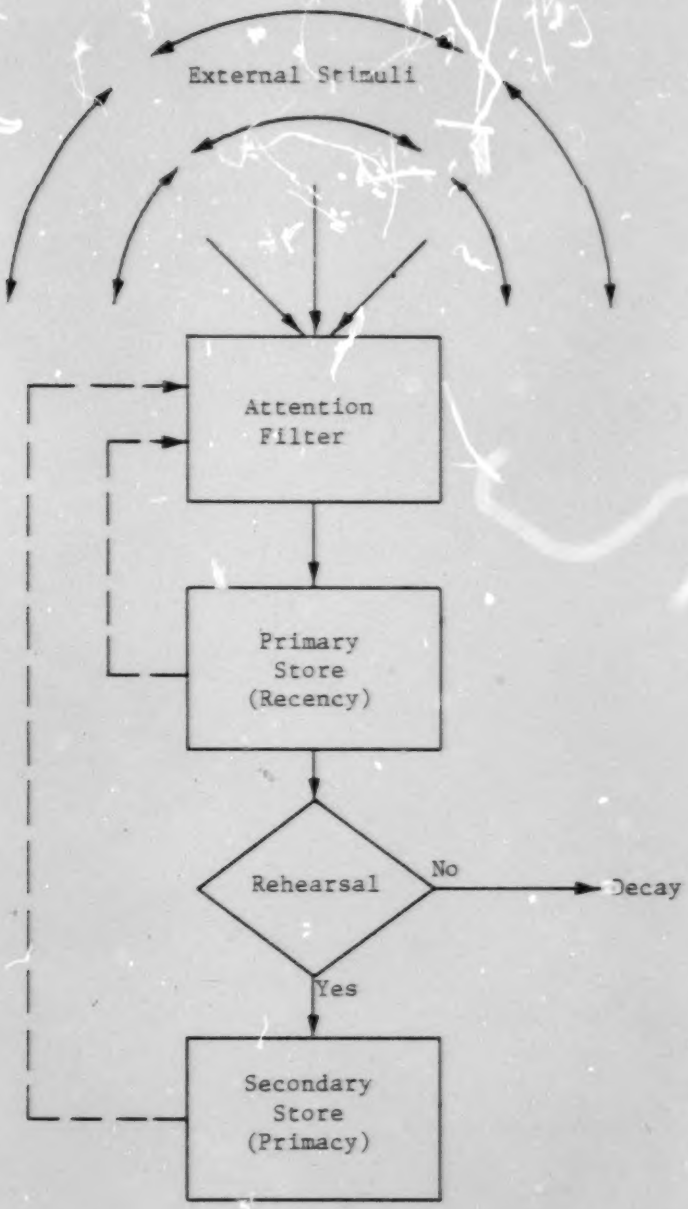

Figure 2. Information flow in STM

Ellis's model delineated a two stage memory system operating in STM. Primary memory receives incoming information from environmental stimuli. It was conceived as being the most inefficient of the three systems, capable of storing only a few items at a time. Storage at this level is transient in nature. due either to the effects of decay or the inflow of new information.

Secondary memory represented greater capacity to store items over a longer time span. It is posited to retain bits of information over a brief span of seconds, or at most, a few minutes. Rehearsal strategies provide the mechanism for transferring information from the primary to the secondary or from secondary to the tertiary levels of memory. Ellis considered the rehearsal strategy the major construct of the model.

Ellis (1970) performed a series of experiments to test his theoretical model. The experiments involved comparing normal subjects with retarded subjects, matched on chronological age. His methodology included the use of a "supraspan input model" which he identified as a sequential input of information beyond the "span of attention." By exceeding the "span of attention," serial position effects could be manifested.

Ellis associated primacy performance with secondary memory. According to this model, this level of memory is accomplished through transfer of information via rehearsal strategies. He found that by increasing the time presentation between items, the normals demonstrated improved performance, whereas, the retardates did not significantly improve. The normal subjects verbally indicated the use of rehearsal strategies whereas the retardates mentioned minimal rehearsal.

Ellis's results indicated that there was no significant difference in performance between normals and retardates on the recency segment. Recency appeared to be invariant regardless of the task length. This evidence led Ellis to believe that the major component of recency was due to primary memory. The Ellis and Hope (1968) experiment indicated that recency diminished more rapidly in the retardate. They hypothesized that the unfilled intervals enabled the normal subjects to use rehearsal strategies which may have helped to re-establish a reminiscence effect in both secondary and primary memory.

Ellis and Anders (1969) investigated the effects of an interpolated probe on primacy and recency performance. Immediately following the presentation of the last position in a 9-digit series, interpolated probes were administered prior to recall in the experimental condition. A control condition was employed which omitted the interpolated probes during the delay period of 7.5 seconds. They found that the overall performance for the experimental condition was significantly lower than that of the control condition. In addition, they observed that the recency performance diminished significantly more than the primacy performance. These results were interpreted as evidence to support the instability of primary memory.

Glanzer and Cunitz (1966) suggested that their findings supported two memory processes in STM. In one experiment, the presentation rate (3, 6, or 8 seconds) and repetition of stimuli (1, 2, or 3 times) were administered. They found that the primacy performance on a list of 20 common nouns was improved as the presentation rate increased. The repetition of stimuli had no effect on primacy performance. They reported in a second study that when recall was delayed (0, 10, or 30

seconds), the recency performance decreased as the time delay increased.

Palmer and Ornstein (1971) studied the effect of immediate and delayed recall in serial probe STM tasks. They instructed one group to employ cumulative rehearsal (CR) strategies. The other group was given to rehearsal (NR) strategy instructions. The two recall conditions were 0 and 15 seconds after presentation. The primacy performance for the CR group was significantly better than the NR group for both recall conditions. In addition, they found that the recency performance for both groups was significantly poorer at the 15 second condition. They suggested that these results supported a primary and secondary memory store in STM.

Encoding Information

It has been suggested by several authors that encoding processes facilitate the retention of information (Bousfield, 1953; Miller, 1956a). The study of encoding processes has involved two separate areas of inquiries.

> The first of the areas is "organization", which means the process of ordering material, of classifying it, and of tagging it with a symbol which will help facilitate retrieval. The second, "mediation" is a facilitation process involving both the stages of storage and retrieval in a manner somewhat different than organization (Cemak, 1972, pp. 144-45).

Organization is considered to occur at stimulus presentation and is a function of the similarities in the stimuli recognized by the subject. Mediation is not predicted on the subject's facility to organize input of similar attributes.

The encoding strategy of chunking would be considered an organizational process. Miller (1956a) introduced a "magical number"--the

number of chunks that can be held in short-term memory for immediate recall. In introducing the "chunk," Miller admitted that the concept was vague.

> The contrast of the terms bit and chunk also serves to highlight the fact that we are not very definite about what constitutes a chunk of information . . . we are dealing with a process of organizing or grouping the input into familiar units or chunks, and a great deal of learning has gone into the formation of these familiar units (p. 93).

There is a fundamental distinction between a conventionally defined amount of material and a chunk. A chunk is independent of the material of which those chunks are manufactured--"five chunks of colors, five chunks of digits, five chunks of words." Miller further elaborated on altering the chunking of material by laboratory training:

> In order to speak more precisely, therefore, we must recognize the importance of grouping or organizing the input sequence into units or chunks. Since the memory span is a fixed number of chunks, we can increase the number of bits of information that it contains simply by building larger and larger chunks, each chunk containing more information than before (p. 93).

Miller described in his article the famous Smith experiment. Smith increased the number of binary digits he could recall from about 12 to 40. He accomplished this task by recoding each sequence of three binary digits into a single, octal (0 through 7) digit. Other experiments cited by Simon (1974) demonstrated similar findings. The evidence seems to indicate that chunking permits the retention of more bits of information.

A few studies have attempted to investigate the effects of mediation strategies on STM. A cumulative rehearsal (CR) strategy represents a technique often used in experimental procedures. The subject is instructed to rehearse serially presented stimuli by stringing each occurring stimulus to the preceding stimuli.

Palmer and Ornstein (1971) investigated the effects of rehearsal instructions on a serial probed-recall task. One group was instructed to employ a CR strategy to rehearse serially presented stimuli. The other group was instructed to use a paired-associate method, i.e., to rehearse words adjacent to one another. A list of ten words was serially presented with a slide projector; each word was presented for 1.75 second with an inter-item rate of .75 second. Their analysis revealed a significantly higher primacy performance for the CR group. There was no statistical difference between the two groups in recency performance.

Fischler, Rundus, and Atkinson (1970) investigated the effects of three different conditions on STM. These conditions consisted of: a silent condition (i.e., the subject could use any strategy); a fixed condition (i.e., the subject could only repeat the item currently displayed); and a free format condition (i.e., the subject was encouraged to include prior items and to vocalize his strategies). They found that the primacy performance in the free and silent conditions was significantly higher than the fixed condition. The silent condition was significantly higher than the two other conditions on recency performance.

A few studies have attempted to examine the effects of externally arranged stimuli on adult STM performance (Bower & Winenz, 1969; Wilkes & Kennedy, 1970). These studies consistently demonstrated the facilitative effects of temporal grouping in STM recall of stimuli. The inducement of pauses within serial lists by the experimenter improved the recall performance of the subjects.

Frank and Rabinovitch (1974) investigated the effects of grouped and ungrouped auditorily presented stimuli varying in length on boys in grades three through five. They found that the temporal grouping of items resulted in a higher recall performance across all grade levels. They suggested that the ability to effectively use rehearsal strategies did not reflect on age variant in auditory STM, i.e., all three groups benefitted from the grouped presentation.

Several studies have attempted to investigate the subject's rehearsal pattern in subject-controlled presentation rates. Rundus and Atkinson (1970) found that subjects employed more time to rehearse items at the beginning of a list. The analysis seemed to indicate a decreasing monotonic probability function between the number of rehearsals and the item's position in the series.

Pinkus and Laughery (1970) observed a "cumulative rehearsal-fast finish" (p. 339, footnote 4) employed by subjects during self-paced presentations of stimuli. The fast finish employed by subjects seemed to be invariant of stimuli length. As the length of stimuli increased, subjects used two or more short pauses followed by a longer pause to process the initial items in the list. The authors indicated that optimal allocation of time seemed to be more important than the total time employed in STM tasks.

Belmont and Butterfield (1971) compared the performance of mildly retarded subjects with normal subjects on a self-paced presentation of serial lists of letters. They found that the normal subjects tended to employ increasingly longer pauses as the number of items increased. The retarded subjects did not exhibit a similar trend in pause lengths. The normal subjects' performance on recall was

significantly higher than the retarded subjects on the primacy portion of the series. They found no difference in recency performance between the two groups. The authors attributed the retarded subjects' performance to a "fast finish" strategy to process all items within the serial lists.

Ellis and Dugas (1968) investigated the differences between experimenter-paced and subject-paced presentations of consonant-vowel-consonant trigrams. The experimenter-paced condition presented the stimuli at a .75 second exposure duration with a 0 second inter-item interval. The subject-controlled condition had an identical exposure rate of .75 second, but the subject could self-monitor the inter-item interval. They found that the primacy performance of the subject-paced condition was significantly higher than the experimenter-paced condition. No significant difference was found for the recency performance between the two groups. The analysis of the latency data revealed a serial position effect at positions three and four for the subject-paced condition. The longer latencies were considered by the authors to reflect the rehearsal strategies employed in primacy performance.

A few studies have attempted to investigate the effects of training rehearsal strategies to improve STM performance. Kellas, Ashcraft, and Johnson (1973) found that mildly retarded adolescents demonstrated improved recall performance after training in cumulative rehearsal strategies. The strategy required the subjects to repeat previous items with the current item in a serial list three times.

Reichhart, Cody, and Borkowski (1975) studied the efficacy of training three active rehearsal strategies with mentally retarded

adolescents. The three training conditions consisted of: a cumulative clustering strategy; a cumulative rehearsal strategy; and, a clustering strategy. The design also employed a control condition in which no rehearsal strategy was trained. The subjects were tested on a self-paced nine-picture series immediately, one day, and two weeks after training. The authors found that the cumulative rehearsal group demonstrated highest recall of items immediately following training. For the one day transfer task, both the cumulative rehearsal and cumulative clustering groups demonstrated higher recall of items than either the clustering or control groups. They found that the cumulative rehearsal strategy was the most efficient method for retarded adolescents with an intelligence quotient (IQ) over 50. The authors also indicated that there was no difference in performance between organically impaired and nonimpaired subjects.

Butterfield, Wambold, and Belmont (1974) performed three experiments in rehearsal training with mildly retarded subjects. They found that the retarded subjects could effectively use rehearsal strategies to improve recall in STM tasks. They suggested that the retarded subjects do not employ strategies unless taught to do so.

Hagen and Kingsley (1968) have shown that nursery-school children improved primacy performance in STM when forced to use a rehearsal strategy. They suggested that their finding supported two distinctive processes in STM.

A few studies have investigated the effects of verbal labeling on STM performance in children. Hagen, Meacham, and Mesibov (1970) investigated the effects of verbal labeling on STM performance across three grade levels (4, 6, and 8). They sequentially presented a series

of eight cards with a black line drawing of an animal and household object adjacent to one another on each card. One group was instructed to label the animal upon presentation of each card. Labeling instructions were not given to the other group. When combining the scores across all three grade levels, they found that the primacy performance for the no label group was significantly higher. Recency performance was found to be significantly higher for the labeling group when this procedure was employed. They suggested that verbal labeling seemed to interfere with the rehearsal strategies employed by subjects to recall primacy items. Their findings seemed to indicate that primacy performance showed regular improvement as a function of chronological age. Recency performance did not exhibit a similar trend. The results from this study provide evidence to support the role of rehearsal in primacy performance. Although primacy performance reflected a developmental trend, the interference effect of verbal labeling across all ages would seem to indicate that rehearsal strategies are employed by younger children in a less efficient manner than older children.

Summary

It has been suggested that the performance of learning disabled children in STM is inadequate as a result of a perceptual deficit which inhibits the organization and storage of information. This interpretation has been predicted on the assumption that STM is primarily a function of sensory store. The investigations employed to study STM have been designed to reflect this a priori assumption.

Contemporary theorists have generally agreed that two distinct processes are operating in STM (Atkinson & Shiffrin, 1968; Ellis, 1970; Waugh & Norman, 1965). If Ellis's Multi-Process Memory Model is applied to the investigation of STM in learning disabled children, their inadequate performance may be viewed within the framework of the two processes employed in STM. The implementation of a "supraspan input model" would manifest a serial position effect. If the learning disabled childrens' primacy performance was inadequate, a rehearsal deficiency could be inferred. If recency performance was inferior, then a perceptual deficit could be inferred.

It has been demonstrated that primacy performance is directly related to the presentation rate of stimuli. Normal subjects' performance on primacy items demonstrated improvement when sufficient time was allocated for rehearsal strategies to be employed. Subjects required more time to rehearse initial items of a serial recall task than was needed for recency items. Recency performance was generally found to be independent of the amount of stimuli to be stored.

Two types of encoding processes have been investigated which facilitate retention. One type, chunking, entails organization of input at the occurrence of stimulus presentation as a function of the similarities in the stimuli. The second strategy, mediation, involves a process whereby an associative link is employed to facilitate recall. A cumulative rehearsal strategy of verbally stringing previously presented items to the current item has been demonstrated to improve STM. Several studies have demonstrated that these encoding processes are amenable to training.

Statement of the Problem

The purpose of this study was twofold. The purpose of the first experiment was to compare SPC performance between learning disabled and normal children across two modalities with two different presentation rates. By examining their performance on the SPC, inadequate STM could be evaluated in terms of primacy and recency performance. Two presentation rates were employed to determine whether a slower presentation facilitated primacy performance for the two groups. Auditory and visual presentations were used to investigate if modality presentation affected performance.

The purpose of the second experiment was to evaluate the effects of training encoding processes in learning disabled children. Two types of encoding training were employed to determine whether differential effects occurred in learning disabled children's SPC performance across two modalities with two different rates of presentation.

Hypotheses

Hypotheses one through four were concerned with the first experiment of this study. Hypotheses five through twelve were concerned with the second experiment.

Hypothesis One. On a short-term memory task employing an auditorily presented seven-digit series at .5-second item duration and a 1-second inter-item interval, the SPC profiles for the learning disabled children and normal children will be parallel.

Hypothesis Two. On a short-term memory task employing an auditorily presented seven-digit series at .5-second item duration and a 2-second inter-item interval, the SPC profiles for the learning

disabled children and normal children will be parallel.

Hypothesis Three. On a short-term memory task employing a visually presented seven-digit series at .5-second item exposure and a 1-second inter-item interval, the SPC profiles for the learning disabled children and normal children will be parallel.

Hypothesis Four. On a short-term memory task employing a visually presented seven-digit series at .5-second item exposure and a 2-second inter-item interval, the SPC profiles for the learning disabled and normal children will be parallel.

Hypothesis Five. On a short-term memory task employing an auditorily presented seven-digit series at .5-second item duration and a 1-second inter-item interval, there will be no difference in the performance of the chunking, verbal stringing, and hawthorne groups at each of the seven positions.

Hypothesis Six. On a short-term memory task employing an auditorily presented seven-digit series at .5-second item duration and a 1-second inter-item interval, there will be no difference in performance among positions for each group.

Hypothesis Seven. On a short-term memory task employing an auditorily presented seven-digit series at .5-second item duration and a 2-second inter-item interval, there will be no difference in the performance of the chunking, verbal stringing, and hawthorne groups at each of the seven positions.

Hypothesis Eight. On a short-term memory task employing an auditorily presented seven-digit series at .5-second item duration and a 2-second iter-item interval, there will be no difference in performance among positions for each group.

Hypothesis Nine. On a short-term memory task employing a visually presented seven-digit series at .5-second item exposure and a 1-second inter-item interval, there will be no difference in the performance of the chunking, verbal stringing, and hawthorne groups at each of the seven positions.

Hypothesis Ten. On a short-term memory task employing a visually presented seven-digit series at .5-second item exposure and a 1-second inter-item interval, there will be no difference in performance among positions for each group.

Hypothesis Eleven. On a short-term memory task employing a visually presented seven-digit series at .5-second item exposure and a 2-second inter-item interval, there will be no difference in the performance of the chunking, verbal stringing, and hawthorne groups at each of the seven positions.

Hypothesis Twelve. On a short-term memory task employing a visually presented seven-digit series at .5-second item exposure and a 2-second inter-item interval, there will be no difference among positions for each group.

Chapter III

PROCEDURE OF THE INVESTIGATION

The procedures employed in this study are reported in two sections. The first section deals with the pretest experiment designed to compare the performance of learning disabled (LD) subjects and normal subjects on the primacy and recency segments of serially presented digit series. Four recall conditions comprised the pretest experiment: two conditions employed auditorily presented stimuli with two different rates of inter-item presentation, and two conditions used visually presented stimuli with two different rates of inter-item presentation. Section II describes the procedures used to train the learning-disabled subjects in different rehearsal strategies. Three different treatments were administered: (1) treatment I employed training emphasizing chunking techniques; (2) treatment II employed training emphasizing verbal stringing techniques, and (3) treatment III employed a hawthorne effect whereby no training in rehearsal strategies was emphasized. A posttest was administered to the three groups upon completion of the treatment period.

Section I

Pretest Design

Recall condition I employed auditorily presented tasks of serial recall. Each position in a task was presented for .5 second and one second of unfilled time was allowed to elapse before the next position

was presented. A total of 10.5 seconds was expended to present an entire sequence of a task.

Recall condition II employed auditorily presented serial recall tasks. For this condition, the .5 second rate of position exposure was maintained, but the inter-item rate was increased to two seconds of unfilled time. Presentation of the entire sequence required 17.5 seconds.

Recall condition III employed visually presented tasks of serial recall. Each position of a sequence was presented for .5 second and one second of unfilled time was allowed to elapse before the next position was exposed. A total of 10.5 seconds was required to present a serial task.

Recall condition IV employed visually presented tasks of serial recall. For this condition, the .5 second rate of position exposure was maintained, but the inter-item rate was increased to two seconds of unfilled time. Presentation of an entire task required 17.5 seconds.

Subjects

Thirty subjects (Ss) were children enrolled in classes for learning disabled (LD) children operated by an Intermediate Unit. Their chronological ages ranged from 81 to 136 months with a mean age of 113.4 months and a standard deviation of 12.9 months. The sample consisted of 27 males and three females.

Thirty Ss enrolled in regular classrooms were selected to serve as a contrast group. They were matched by chronological age with the LD Ss. Sex was not considered to be a factor influencing memory differences. Studies (McCarver, 1972; Harris & Burke, 1972) indicated no

differences between boys and girls, CA range 5-11 years, on memory tasks employing digit spans. The Ss' chronological ages ranged from 85 months to 134 months with a mean age of 113.37 months and a standard deviation of 12.15 months. The normal Ss included 15 males and 15 females.

Experimental Materials Design

In order to accommodate a "supraspan input model," a span of seven digits was selected to comprise each recall task. The selection was predicated on the norms for digit span recall associated with the particular age range under investigation. A range of from five to six digits forward was indicated as a representative sample of performance for this age range (Wechsler, 1955). A span of seven digits was then considered to be of sufficient length to produce a serial position effect.

Each of the four recall conditions was composed of twenty-seven serial recall tasks. Each serial recall task had seven digits (one through nine) drawn from a table of random numbers. No digit was allowed to appear more than once in a given task. If any digit appeared adjacent to itself (i.e., the last digit of the preceding task and the initial digit of the ensuing task), a new digit was drawn to replace either digit in one of the two series. Inordinate repetition of a digit in the same position across tasks was avoided.

The Ss' responses were scored on the basis of the number of correct responses made. S's response for each position was scored correct if it matched the position indicated in the stimulus series.

Auditory Recall Conditions (I & II). The auditory recall conditions were recorded on a Scotch magnetic tape cassette by a female.

The same voice was employed throughout the study. An effort was made to maintain a constant pitch and volume throughout the entire digit span presentation. A Compass Instrument stop watch was used to monitor the time parameters for each condition. A pure tone was recorded to signify the end of a given serial task.

The serial tasks were recorded and presented on a Panasonic portable cassette tape recorder, model number RQ4135. Each subject was located approximately three to four feet from the recorder during the administration of the auditory recall conditions.

Preliminary instructions were given to S:

> Listen carefully. You will hear some numbers. You are not expected to remember all the numbers, just try to remember as many as you can. When you hear this sound (pure tone), say the numbers exactly as you heard them. Now let's try a practice trial.

The S was then given the practice trial. After S orally recalled the practice trial, he was told, "Now you will have more numbers to remember." The same instructions were repeated prior to the start of each day's auditory sessions. In order to indicate the subsequent recall condition, S was told, "Now the numbers will be faster" or "now the numbers will be slower," whichever was indicated for that day's session. A practice trial was given to allow S an opportunity to adjust to the altered rate of presentation.

Visual Recall Conditions (III & IV). All digits employed in the visual recall conditions were photographed with Kodak DTH (ASA 125) color film. A black digit, two inches high, centrally located on a five x eight white index card was the composition to be photographed. All photography was done with a Minolta 101-SRT, 35 millimeter camera, 1:1.7 Rokkor lens with three 52 millimeter close-up lenses. The light

source for the photography consisted of two 3400K photolamps, which were directed toward the center of the photographic surface. The camera was mounted on a reversed tripod at a focal length of 14 inches from the material. A shutter speed of 1/125 of a second and an aperture of f 4.0 were used to photograph each digit.

The time parameters for each condition were recorded on a Scotch magnetic tape cassette by means of a synchronized pulse switch on a Cinemasound 2000 recorder/projector. The aforementioned female was used to record the instructions for each visual condition. A Compass Instrument stop watch was used to monitor the time parameters for each condition. The end of a given serial task was indicated to the S by means of a slide which was constructed from green cellophane paper.

The photographic transparancies were presented in a darkened room to S by means of a Cinemasound 2000 (Half-track) recorder/projector on a wall located approximately eight feet away. A Lafayette manual tachistoscope (model 43015) with a .5 second time setting was used to control the rate of exposure. The experimenter (E) manually maintained the position exposure as the positions were advanced automatically by the Cinemasound 2000.

For the visual recall conditions, preliminary instructions were given to S:

> Watch carefully. You will see some numbers. You are not expected to remember all the numbers, just try to remember as many as you can. When you see the green light, say the numbers exactly as you saw them. Now let's try a practice trial.

The S was then administered a practice trial. After S orally recalled the task, he was told, "Now you will have more numbers to remember." The same instructions were administered prior to the start of each day's

visual session. In order to indicate the recall conditions, S was told, "Now the numbers will be faster" or "Now the numbers will be slower," whichever was applicable to that day's session. A practice trial was then presented to allow S an opportunity to adapt to the altered presentation rate.

Experimental Procedures

The order of presentation for the visual and auditory recall conditions was counterbalanced; the modality and inter-item rate of presentation were rotated. Figure 3 depicts the order of presentation for the four recall conditions.

Each S was escorted to the testing room from the classroom by E and seated next to a table. The E recorded S's responses on a scoring sheet after each serial task. After the day's administration was completed, S was brought back to his classroom by E. The same procedure was maintained for each S.

Administration of the four recall conditions required three days. Daily sessions were scheduled for half-hour periods. The Ss unable to attend prearranged sessions were tested at a later date. All Ss completed the four recall conditions.

Experimenters. Two female graduate students majoring in special education served as Es during the pretest condition. They were provided with three hours of training prior to the administration of the pretest. One of the Es withdrew from the study at the conclusion of the pretest phase. She was replaced by a male graduate student majoring in art education. Both Es were given five hours of training prior to the introduction of the treatment phase and the new E was given an additional

Day 1 (36 tasks)	Auditory	Auditory	Visual	Visual
	.5 sec. exposure with 1 sec. inter-item rate (9)	.5 sec. exposure with 2 sec. inter-item rate (9)	.5 sec. exposure with 1 sec. inter-item rate (9)	.5 sec. exposure with 2 sec. inter-item rate (9)
Day 2 (36 tasks)	Visual	Visual	Auditory	Auditory
	.5 sec. exposure with 2 sec. inter-item rate (9)	.5 sec. exposure with 1 sec. inter-item rate (9)	.5 sec. exposure with 2 sec. inter-item rate (9)	.5 sec. exposure with 1 sec. inter-item rate (9)
Day 3 (36 tasks)	Auditory	Auditory	Visual	Visual
	.5 sec. exposure with 1 sec. inter-item rate (9)	.5 sec. exposure with 2 sec. inter-item rate (9)	.5 sec. exposure with 1 sec. inter-item rate (9)	.5 sec. exposure with 2 sec. inter-item rate (9)

Figure 3. Counterbalance of recall conditions

three hours training in the administration of the recall conditions.

Design for Analyzing Pretest Data

A multivariate profile analysis for two independent groups (Morrison, 1967) was used to analyze the data for hypotheses one through four. Group 1 was composed of 30 normal subjects and Group 2 of 30 subjects diagnosed as learning disabled. Figure 4 represents an illustration of how the data were arranged with each row representing the vector of a different subject.

In order for the F tests to be valid, the observations are assumed to have been drawn from multinormal populations with a common covariance matrix. Ito and Schull (1964) have demonstrated that if sample sizes are equal, then unequal covariance matrices have no effect upon Type 1 error probability. Since the analyses involve equal sample sizes, the threat of making a Type 1 error was considered to be exact.

Section II

Three different treatments were administered to the learning disabled subjects: (1) treatment I employed training emphasizing chunking techniques for rehearsal strategies; (2) treatment II employed training emphasizing verbal stringing techniques for rehearsal strategies, and (3) treatment III employed a Hawthorne effect whereby no training in rehearsal strategies was emphasized. Each subject received only one treatment.

	Group 1 Responses			Group 2 Responses		
	1	...	7	1	...	7
	x_{111}	...	x_{117}	x_{211}	...	x_{217}
	...	...	...	...	...	...
	x_1N_11	...	x_1N_17	x_2N_11	...	x_2N_27
Response Means	$\bar{X}_{11}$	...	$\bar{X}_{17}$	$\bar{X}_{21}$	...	$\bar{X}_{27}$

Figure 4. Observations for profile analysis of two independent groups

Subjects

The learning disabled subjects were stratified into blocks of three subjects on the basis of the pretest scores and randomly assigned to one of the three treatments. To obtain a score for stratification, the average pretest score for all seven positions under all four conditions was computed. Table 1 contains the means and standard deviations for the three treatment groups.

Table 1

Means and standard deviations of overall pretest scores for the three treatment groups (n=10)

Treatment I	Treatment II	Treatment III
$\bar{X}$=.30	$\bar{X}$=.27	$\bar{X}$=.27
S=.11	S=.10	S=.12

The Ss were assigned to pairs within each treatment on the basis of pretest scores. Administrative arrangements prohibited the assignment of six Ss to pairs. These Ss were then given individual tutoring in their respective treatments. The six Ss represented members of all three treatments as follows: (1) one S in treatment I, (2) one S in treatment II, and (3) four Ss in treatment III.

Materials

The experimental materials employed in the treatment phase were only applicable to treatment I (chunking) and treatment II (verbal

stringing). Individual digits, two inches high were stenciled onto 3 x 3 inch white cards. For treatment I, two shades of green (dark and light) were employed for instructional purposes. For treatment II, only one shade of green (dark) was used. A 4 x 24 inch piece of cardboard was used as a manual tachistoscope.

Treatment

The entire treatment phase consisted of three half-hour sessions per week for a period of six weeks. The mean number of actual hours for each treatment group was slightly less than nine hours. The mean time per treatment was: (1) chunking group's mean time equalled 8.65 hours; (2) verbal stringing group's mean time equalled 8.72 hours, and (3) hawthorne group's mean time equalled 8.52 hours.

Treatment I. Treatment I employed training techniques associated with "chunking" input sequences. This treatment incorporated the rehearsal strategy of organizing serial input into units or chunks. The training emphasized a hierarchy of seven objectives ranging from the accurate recall of a two to seven digit series. The Ss were instructed to "chunk" each series of digits into units cued visually by color coded cards and auditorily by E. For example, the seven digit series 7486953 was visually presented as 7-48-69-53 and auditorily presented as "seven forty-eight, sixty-nine, fifty-three."

The S's progression from one objective to the next was monitored on the basis of his mastery of the previous objective. The criterion for mastery on each objective gradually decreased as the length of the series increased. The basis for differential criteria was considered necessary to enable S's completion of all seven objectives.

Treatment II. Treatment II employed training techniques associated with "verbally stringing" input sequences. This treatment emphasized the strategy of verbally stringing each stimulus to the preceding stimuli. Training encompassed a hierarchy of seven objectives ranging from the accurate recall of a one to seven digit series. The Ss were instructed to verbally string each series of digits presented visually on cards and auditorily by E. For example, the seven digit series 7486953 was both visually and auditorily presented as "7-4-8-6-9-5-3." S was instructed to repeat orally the digit series from the beginning as each succeeding digit appeared. In the aforementioned example, S's responses to input through digit 8 include "7," "7-4," "7-4-8."

The S's progression from one objective to the next was predicated on his mastery of the previous objective. The mastery criterion for each objective gradually decreased as the length of the series increased. Differential mastery criteria were established to enable S's completion of all seven objectives.

Treatment III. Treatment III did not employ techniques associated with rehearsal strategies. This treatment provided experimenter-subject interaction on tasks unrelated to formal training in rehearsal strategies. Treatment sessions were composed of activities specifically designed by S's teacher to supplement S's classroom instruction. The E provided tutorial assistance to the Ss during these individualized activities.

Posttest Recall Conditions

Posttests were administered to the learning disabled subjects upon completion of the treatment phase. The four recall conditions that were employed during the pretest stage were maintained. Administrative considerations discussed in the pretest phase were also continued. New randomizations were generated to determine digit composition for the tasks of serial recall.

All Ss were individually administered the four recall conditions upon completion of the treatment phase. Administration of the posttest was scheduled in a prearranged order to balance extraneous environmental factors. Specifically, one S from each treatment was administered the posttest before another S from that same treatment was administered the posttest. The experimental procedures delineating the pretest condition were also observed during the posttest condition.

Design for Analyzing Posttest Data

The design for analyzing the posttest data (hypotheses five through twelve) was composed of two major analyses. A univariate analysis of variance was performed on the gain scores at each position for each dependent measure to test the a priori hypothesis of no difference among the experimental groups. To test the hypothesis of no difference among positions within each experimental group for each dependent measure, a single-factor design with repeated measures was used to analyze the gain scores.

Chapter IV

EXPERIMENTAL RESULTS

The experimental results for this study are reported in two sections. The first section deals with pretests comparing normal and learning disabled (LD) subjects on the four dependent measures. The four dependent variables (one-second auditory, two-second auditory, one-second visual, and two-second visual rates of presentation) are treated separately. In order to test the hypothesis of parallelism between profiles for each group, a profile analysis was performed for each dependent measure. If the profile analysis indicated a significant response by group interaction, then analyses were performed to determine simple between groups effect and simple within groups effect. Section II contains a discussion of the posttest data comparing the three experimental groups. Univariate analyses of variance were performed on gain scores to test the a priori hypothesis of no difference among experimental groups for each position on each dependent measure. A single-factor design with repeated measures was used to test the hypothesis of no difference among positions for each experimental group on each dependent measure. Summary analyses are presented for each section. All calculations were computed to the eighth decimal position, but have been rounded to the second decimal position for presentation in the tables.

Section I

Hypothesis One

The means and standard deviations for Group 1 (normal) and Group 2 (LD) are presented in Table 2 for hypothesis one. Appendix A contains the variance-covariance matrices for Group 1 and Group 2. Hypothesis one was concerned with the differences in performance between the groups across seven positions of the digit span for the one-second auditory rate of presentation.

Table 2

Means and standard deviations of the percentage correct at each position for hypothesis one

	Serial Position						
	1	2	3	4	5	6	7
Group 1 (normal) n=30	$\bar{X}$=.70	$\bar{X}$=.50	$\bar{X}$=.40	$\bar{X}$=.32	$\bar{X}$=.32	$\bar{X}$=.35	$\bar{X}$=.61
	S=.22	S=.23	S=.21	S=.18	S=.16	S=.16	S=.21
Group 2 (LD) n=30	$\bar{X}$=.41	$\bar{X}$=.26	$\bar{X}$=.21	$\bar{X}$=.15	$\bar{X}$=.14	$\bar{X}$=.24	$\bar{X}$=.53
	S=.27	S=.23	S=.18	S=.14	S=.08	S=.11	S=.18

A profile analysis (Morrison, 1967, pp. 141-153) was then performed to determine if the population mean profiles were parallel. The analysis revealed that there was a significant response by group interaction ($F = 2.45$, $dF = 6.53$). Figure 5 contains a graphic presentation of the significant interaction.

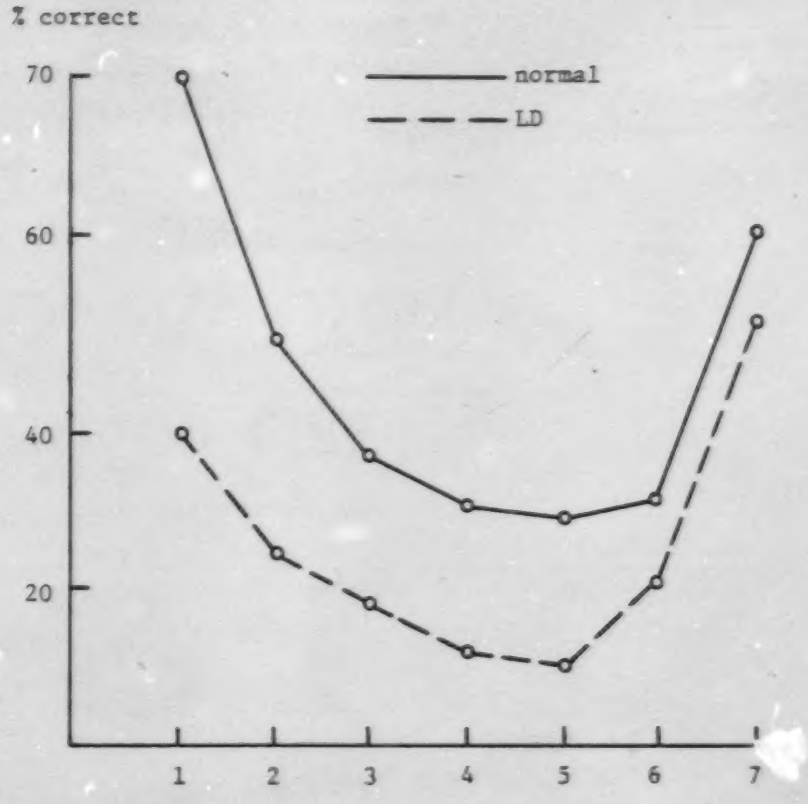

Figure 5. Mean percentage correct for normal and learning disabled groups across seven positions at the one-second auditory condition: hypothesis one.

An analysis of simple effects between groups by position was then carried out, the results of which are reported in Table 3. Group 1 had significant higher mean performances on positions one through six. The difference in performance between the two groups was not significant for position seven.

A simple within effects for each group was then carried out; the results for Group 1 are contained in Table 4. The analysis of variance revealed that there was a significant simple within effects for Group 1. The Tukey (WSD) procedure (Games, 1972) was then used with individual variances and covariances for each position[1] to test the difference between all pairs of means. Table 5 contains the results for this analysis. The Tukey procedure indicated that there were significant differences between the following pairwise comparisons: (1) position five with positions three, two, seven, and one; (2) position four with positions three, two, seven, and one; (3) position six with positions two, seven, and one; (4) position three with positions two, seven, and one, and (5) position two with position one. The remaining comparisons of mean performance by position were not significant.

The results of the simple within effects analysis for Group 2 are contained in Table 6. The analysis of variance revealed a significant simple within effects for Group 2. Table 7 contains the results for the Tukey (WSD) procedure to test the difference between all pairs of means. Individual variances and covariances were used to calculate the obtained t-statistics. This analysis revealed that there were

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[1]This procedure was followed throughout the analysis whenever the homogeneity of variance could not be assumed.

Table 3

Summary table for independent t-tests for simple between effects for hypothesis one

Position	t value	dF
1	4.62*	58
2	4.00*	58
3	3.80*	58
4	4.30*	58
5	5.41*	58
6	2.96*	58
7	1.51*	58

*$t_{.05/2,58}=2.01$

Table 4

Summary table for analysis of variance for simple within effects for group 1 for hypothesis one

Source of Variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	5.52	29	.19	
Within Subjects	6.69	180		
J (positions)	4.14	6	.69	47.21*
residual	2.55	174	.01	
Total	12.21	209		

*$.05F(6,174)=217$

Table 5

Summary table for Tukey (WSD) procedure for simple within effect for group 1 for hypothesis one

Order	5	4	6	3	2	7	1
5				**	**	**	**
4				**	**	**	**
6					**	**	**
3					**	**	**
2							**

*.05^{q}(7,174)=3.00[a]

[a]Critical value expressed in t-statistic

Table 6

Summary table for analysis of variance for simple within effects of group 2 for hypothesis one

Source of Variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	2.61	29	.09	
Within Subjects	7.62	180		
J (positions)	3.75	6	.62	28.03*
residual	3.88	174	.02	
Total	10.23	209		

*.05^{F}(6,174)=2.17

Table 7

Summary table for Tukey (WSD) procedure for simple within effect for group 2 for hypothesis one

Order	5	4	3	6	2	1	7
5				**	**	**	**
4			**		**	**	**
3						**	**
6						**	**
2						**	**

*.05^{q}(7,174)=3.00^{a}

[a]Critical value expressed in t-statistic

significant differences between the following pairwise comparisons: (1) position five with positions six, two, one, and seven; (2) position four with positions three, two, one, and seven; (3) position three with positions one and seven; (4) position six with position seven, and (5) position two with positions one and seven. The remaining pairwise comparisons were not significant.

Hypothesis Two

The means and standard deviations for Group 1 (normal) and Group 2 (LD) are presented in Table 8 for hypothesis two. Appendix A contains the variance-covariance matrices for Group 1 and Group 2. Hypothesis two was concerned with the differences in performance between the two groups across seven positions at the two-second auditory rate of presentation.

Table 8

Means and standard deviations of the percentage correct at each position for hypothesis two

	Serial Position						
	1	2	3	4	5	6	7
Group 1 (normal) n=30	$\bar{X}$=.68	$\bar{X}$=.51	$\bar{X}$=.36	$\bar{X}$=.32	$\bar{X}$=.31	$\bar{X}$=.36	$\bar{X}$=.62
	S=.26	S=.25	S=.20	S=.20	S=.19	S=.19	S=.21
Group 2 (LD) n=30	$\bar{X}$=.39	$\bar{X}$=.26	$\bar{X}$=.17	$\bar{X}$=.17	$\bar{X}$=.13	$\bar{X}$=.25	$\bar{X}$=.50
	S=.28	S=.24	S=.18	S=.17	S=.11	S=.14	S=.20

A profile analysis was then performed to determine if the population mean profiles were parallel. The analysis indicated that there was a significant response by group interaction (F=3.01, dF=6,53). Figure 6 represents the graphic illustration of the significant interaction for hypothesis two.

An analysis of simple effects between groups by position was then carried out, the results of which are reported in Table 9. Simple between effects analysis indicated that the mean performances for Group 1 were significantly higher across all seven positions.

A simple within effects analysis for each group was then performed; the results for Group 1 are contained in Table 10. The analysis indicated that there was a significant within effects for Group 1. The Tukey (WSD) procedure was then used with the individual variances and covariances for each position to test the difference between all pairs of means. Table 11 contains the results for this

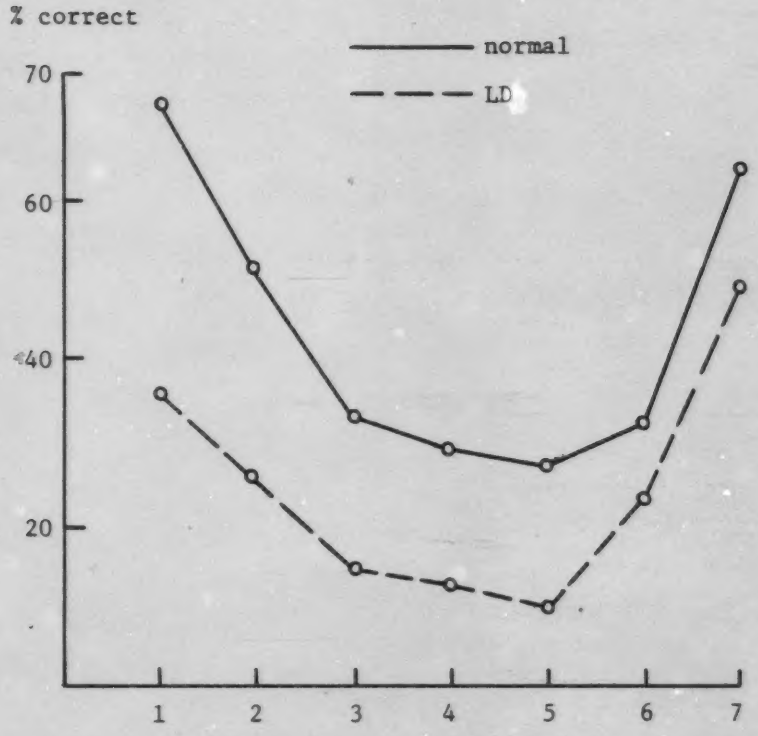

Figure 6. Mean percentage correct for normal and learning disabled groups across seven positions at the two-second auditory condition: hypothesis two.

Table 9

Summary table for independent t-tests for simple between effects for hypothesis two

Position	t value	dF
1	4.22*	58
2	4.12*	58
3	3.69*	58
4	3.26*	58
5	4.52*	58
6	2.63*	58
7	2.26*	58

*t.05/2,58=2.01

Table 10

Summary table for analysis of variance for simple within effects of group 1 for hypothesis two

Source of Variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	6.43	29	.22	
Within Subjects	7.14	180		
J (positions)	4.19	6	.70	41.20*
residual	2.95	174	.02	
Total	13.57	209		

*.05F(6,174)=2.17

Table 11

Summary table for Tukey (WSD) procedure for simple within effect for group 1 for hypothesis two

Order	5	4	3	6	2	7	1
5					**	**	**
4					**	**	**
3					**	**	**
6					**	**	**
2							**

*$8.05^{q}(7,174)=3.00^{a}$

[a]Critical value expressed in t-statistic

analysis. The Tukey procedure revealed that there were significant differences between the following pairwise comparisons: (1) position five with positions two, seven, and one; (2) position four with positions two, seven, and one; (3) position three with positions two, seven, and one; (4) position six with positions two, seven, and one, and (5) position two with position one. The remaining pairwise comparisons were not significant.

The results for the analysis of variance for simple within effects for Group 2 are contained in Table 12. The analysis of variance indicated that there was a significant within effects for Group 2. The Tukey (WSD) procedure was then used with the individual variances and covariances for each position to test the difference between all pairs of means, the results of which are reported in Table 13. The Tukey procedure revealed that there were significant differences between the

Table 12

Summary table for analysis of variance for simple within effects of group 2 for hypothesis two

Source of Variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	3.70	29	.13	
Within Subjects	7.34	180		
J (positions)	3.19	6	.53	22.23*
residual	4.16	174	.02	
Total	11.04	209		

*$.05^{F}(6,174)=2.17$

Table 13

Summary table for Tukey (WSD) procedure for simple within effect for group 2 for hypothesis two

Order	5	4	3	6	2	1	7
5				**	**	**	**
4					**	**	**
3					**	**	**
6							**
2						**	**

*$.05^{q}(7,174)=3.00^{a}$

[a]Critical value expressed in t-statistic

following pairwise comparisons: (1) position five with positions six, two, one, and seven; (2) position four with positions two, one, and seven; (3) position three with positions two, one, and seven; (4) position six with position seven, and (5) position two with positions one and seven. All other pairwise comparisons between means were not significant.

Hypothesis Three

The means and standard deviations for Group 1 (normal) and Group 2 (LD) are presented in Table 14 for hypothesis three. Appendix A contains the variance-covariance matrices for Group 1 and Group 2. Hypothesis three was concerned with the differences in mean performance between the two groups across seven positions for the one-second visual rate of presentation.

A profile analysis was then performed to test if the population mean profiles were parallel. The analysis revealed that there was not a significant response by group interaction ($F=1.56$, $dF=6,53$). The graphic representation of the two profiles for hypothesis three are contained in Figure 7.

An analysis of the mean between effects was then performed to test if the two profiles had equivalent profile levels. The analysis indicated that there was a significant difference at each position favoring the mean performance of Group 1 ($t=5.18$, $dF=58$).

An analysis of the main within effect was then carried out to test the equivalence of parameters in the seven positions. The analysis revealed that there was a significant main within effects for the one-second visual rate of presentation ($F=46.85$, $dF=6.53$). Table 15

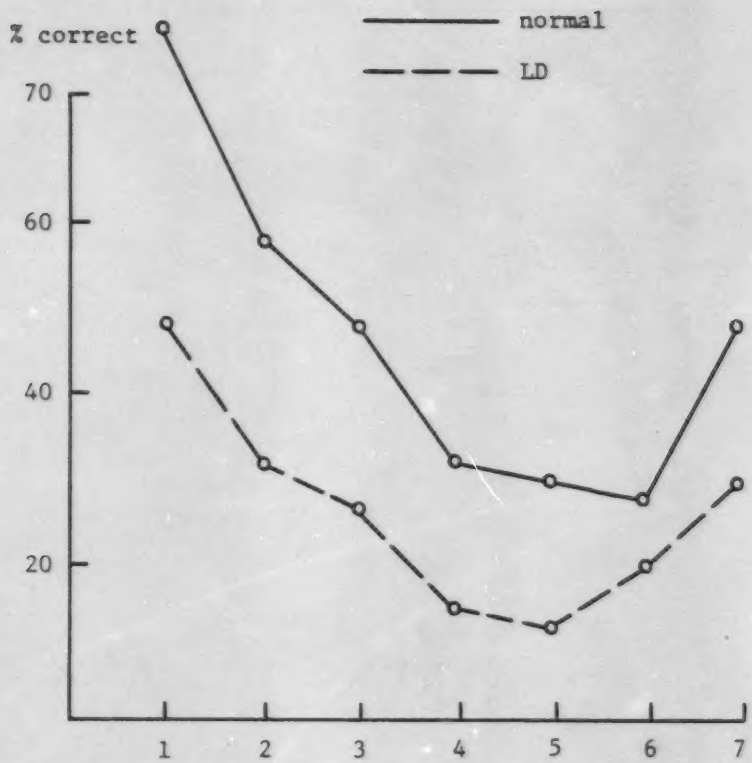

Figure 7. Mean percentage correct for normal and learning disabled groups across seven positions at the one-second visual condition: hypothesis three.

Table 14

Means and standard deviations of the percentage correct at each position for hypothesis three

	Serial Position						
	1	2	3	4	5	6	7
Group 1 (normal) n=30	$\bar{X}$=.76	$\bar{X}$=.59	$\bar{X}$=.47	$\bar{X}$=.37	$\bar{X}$=.36	$\bar{X}$=.36	$\bar{X}$=.45
	S=.21	S=.21	S=.20	S=.17	S=.20	S=.19	S=.19
Group 2 (LD) n=30	$\bar{X}$=.47	$\bar{X}$=.37	$\bar{X}$=.26	$\bar{X}$=.18	$\bar{X}$=.14	$\bar{X}$=.21	$\bar{X}$=.30
	S=.25	S=.24	S=.24	S=.12	S=.12	S=.14	S=.14

Table 15

Summary table for simultaneous confidence intervals for main within effects analysis for hypothesis three

$\bar{x}'$ = [.6163, .4788, .3678, .2746, .2523, .2825, .3777]

Critical value: $.05F(6,53) = 2.34$

position 1- position 2:	$.0992 \leq u_1 - u_2 \leq .1758$
position 1- position 3:	$.1999 \leq u_1 - u_3 \leq .2971$
position 1- position 4:	$.2884 \leq u_1 - u_4 \leq .3950$
position 1- position 5:	$.3053 \leq u_1 - u_5 \leq .4227$
position 1- position 6:	$.2664 \leq u_1 - u_6 \leq .4032$
position 1- position 7:	$.1647 \leq u_1 - u_7 \leq .3125$
position 2- position 3:	$.0772 \leq u_2 - u_3 \leq .1498$
position 2- position 4:	$.1640 \leq u_2 - u_4 \leq .2444$
position 2- position 5:	$.1796 \leq u_2 - u_5 \leq .2734$
position 2- position 6:	$.1375 \leq u_2 - u_6 \leq .2551$
position 2- position 7:	$.0328 \leq u_2 - u_7 \leq .1694$
position 3- position 4:	$.0614 \leq u_3 - u_4 \leq .1250$
position 3- position 5:	$.0776 \leq u_3 - u_5 \leq .1534$
position 3- position 6:	$.0364 \leq u_3 - u_6 \leq .1342$
position 3- position 7:	$-.0667 \leq u_3 - u_7 \leq .0469$
position 4- position 5:	$-.0109 \leq u_4 - u_5 \leq .0555$
position 4- position 6:	$-.0493 \leq u_4 - u_6 \leq .0335$
position 4- position 7:	$-.1539 \leq u_4 - u_7 \leq -.0523$
position 5- position 6:	$-.0638 \leq u_5 - u_6 \leq -.0034$
position 5- position 7:	$-.1733 \leq u_5 - u_7 \leq -.0775$
position 6- position 7:	$-.1326 \leq u_6 - u_7 \leq -.0578$

contains a pairwise comparison of positions by means of simultaneous confidence intervals. The simultaneous confidence intervals on the differences between positions of the grand mean vector indicated that only four comparisons were not significant: (1) position three with position seven; (2) position four with positions five and six, and (3) position five with position six. The remaining differences between positions of the grand mean vector were found to be significant.

Hypothesis Four

The means and standard deviations for Group 1 (normal) and Group 2 (LD) are contained in Table 16 for hypothesis four. Appendix A contains the variance-covariance matrices for Group 1 and Group 2. Hypothesis four was concerned with the differences in performance between the two groups across seven positions of the digit span for the two-second visual rate of presentation.

A profile analysis was then performed to determine if the population mean profiles were parallel. The analysis indicated that there was a significant response by group interaction ($F=3.41$, $dF=6,53$). Figure 8 contains a graphic representation of the significant interaction for hypothesis four.

An analysis of simple effects between groups by position was then carried out, the results of which are reported in Table 17. The analysis indicated that the mean performance for Group 1 was significantly higher across all seven positions.

A simple within effects analysis for each group was then performed; the results for Group 1 are contained in Table 18. The analysis of variance indicated that there was a significant simple

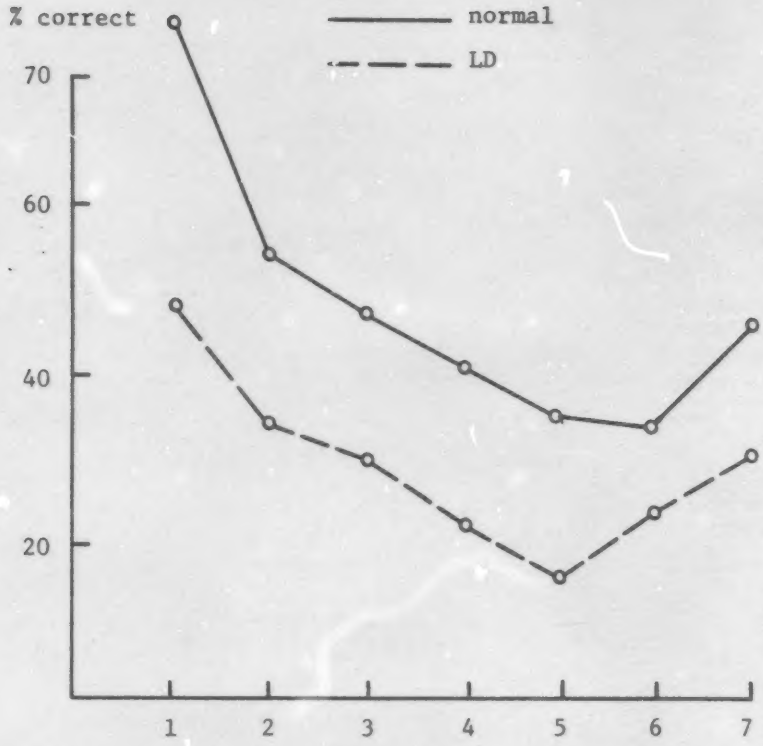

Figure 8. Mean percentage correct for normal and learning disabled groups across seven positions at the two-second visual condition: hypothesis four.

Table 16

Means and standard deviations of the percentage correct at each position for hypothesis four

	Serial Position						
	1	2	3	4	5	6	7
Group 1 (normal) n=30	$\bar{X}$=.75	$\bar{X}$=.56	$\bar{X}$=.47	$\bar{X}$=.40	$\bar{X}$=.37	$\bar{X}$=.37	$\bar{X}$=.47
	S=.21	S=.20	S=.22	S=.20	S=.20	S=.17	S=.16
Group 2 (LD) n=30	$\bar{X}$=.49	$\bar{X}$=.38	$\bar{X}$=.29	$\bar{X}$=.22	$\bar{X}$=.16	$\bar{X}$=.23	$\bar{X}$=.35
	S=.24	S=.22	S=.19	S=.15	S=.11	S=.12	S=.16

Table 17

Summary table for independent t-tests for simple between effects for hypothesis four

Position	t value	dF
1	4.51*	58
2	3.57*	58
3	3.58*	58
4	4.06*	58
5	5.21*	58
6	3.50*	58
7	2.72*	58

*t.[illegible]/2,58=2.01

Table 18

Summary table for analysis of variance for simple within effects for group 1 for hypothesis four

Source of Variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	5.86	29	.20	
Within Subjects	5.39	180		
J (positions)	3.31	6	.55	45.94*
residual	2.09	174	.01	
Total	11.25	209		

*$.05F(6,174)=2.17$

within effects for Group 1. The Tukey (WSD) procedure was then used with the individual variances and covariances for each position to test the difference between all pairs of means. Table 19 contains the results for this analysis. The Tukey procedure revealed that there were significant differences between the following pairwise comparisons: (1) position six with positions seven, three, two, and one; (2) position five with positions seven, three, two, and one; (3) position four with positions two and one; (4) position seven with positions two and one; (5) position three with positions two and one, and (6) position two with position one. The remaining pairwise comparisons were not significant.

The results for the analysis of variance for Group 2 are contained in Table 20. The analysis indicated that there was a significant simple within effects for Group 2. The Tukey (WSD) procedure

Table 19

Summary table for Tukey (WSD) procedure for simple within effect for group 1 for hypothesis four

Order	6	5	4	7	3	2	1
6				**	**	**	**
5				**	**	**	**
4						**	**
7						**	**
3						**	**
2							**

*.05^{q}(7,174)=3.00[a]

[a]Critical value expressed in t-statistic

Table 20

Summary table for analysis of variance for simple within effects for group 2 for hypothesis four

Source of variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	3.48	29		
Within Subjects	4.92	180		
J (positions)	2.25	6	.37	24.38*
residual	2.67	174	.02	
Total	8.40	209		

*.05^{F}(6,174)=2.17

was then used with the individual variances and covariances for each position to test the difference between all pairs of means; the results are reported in Table 21. The Tukey procedure revealed that there were significant differences between the following pairwise comparisons: (1) position five with positions six, three, seven, two, and one; (2) position four with positions seven, three, two, and one; (3) position six with positions seven, two, and one; (4) position three with positions two and one, and (5) position two with position one. The remaining pairwise comparisons were not significant.

Summary

Hypotheses one through four were concerned with pretest performances contrasting normal and learning disabled subjects' profiles on the four dependent measures. The summary for each hypothesis is presented separately.

Hypothesis One. Hypothesis one was concerned with whether the mean performances of the two groups across seven positions was parallel for the one-second auditory rate of presentation. The profile analysis indicated that there was a significant response by group interaction for hypothesis one. An analysis of simple effects between groups revealed that Group 1 performed significantly higher than Group 2 at positions one through six. No significant difference was found between the two groups at position seven. Simple within effects analysis for each group indicated that there was a significant simple within effects for both groups. The Tukey (WSD) procedure for Group 1 indicated that the following pairwise comparisons were significant: (1) positions five and four with positions three, two, seven, and one; (2) positions six

Table 21

Summary table for Tukey (WSD) procedure for simple within effect for group 2 for hypothesis four

Order	5	4	6	3	7	2	1
5			**	**	**	**	**
4				**	**	**	**
6					**	**	**
3						**	**
2							**

*.05^{q}(7,174)=3.00[a]

[a]Critical value expressed in t-statistic

and three with positions two, seven, and one, and (3) position two with position one. For Group 2, the Tukey (WSD) procedure revealed that there were significant differences between the following pairwise comparisons: (1) position five with positions six, two, one, and seven; (2) position four with positions three, two, one, and seven; (3) position three with positions one and seven; (4) position six with seven, and (5) position two with positions one and seven. The remaining pairwise comparisons for both groups were not significant.

Hypothesis Two. Hypothesis two was concerned with whether the mean performance of the two groups across seven positions was parallel for the two-second auditory rate of presentation. The profile analysis revealed that there was a significant response by group interaction for hypothesis two. An analysis of simple effects between groups indicated that Group 1 performed significantly higher than Group 2 across all

seven positions. Simple within effects analysis for each group indicated that there was a significant simple within effects for both groups. The Tukey (WSD) procedure for Group 1 revealed that there were significant differences between the following pairwise comparisons: (1) positions five, four, three, and six with positions two, seven, and one, and (2) position two with position one. For Group 2, the Tukey (WSD) procedure indicated that there were significant differences between the following pairwise comparisons: (1) position five with positions six, two, one, and seven; (2) positions four and three with positions two, one, and seven; (3) position six with position seven, and (4) position two with positions one and seven. All other pairwise comparisons for both groups were not significant.

Hypothesis Three. Hypothesis three was concerned with whether the mean performance of the two groups across seven positions was parallel for the one-second visual rate of presentation. The profile analysis revealed that there was not a significant response by group interaction for hypothesis three. An analysis of the main between effects was performed to test if the two profiles had equivalent levels. This analysis indicated that there were significant differences across all seven positions favoring Group 1. An analysis of main within effects was carried out to test the equivalence of parameters in the seven positions. The analysis by means of simultaneous confidence intervals indicated that only four comparisons were nonsignificant: (1) position three with position seven; (2) position four with positions five and six, and (3) position five with position six. The remaining differences between positions of the grand mean vector were significant.

Hypothesis Four. Hypothesis four was concerned with whether the mean performance of the two groups across seven positions was parallel for the two-second visual rate of presentation. The profile analysis indicated that there was a significant response by group interaction for hypothesis four. An analysis of simple effect between groups revealed that the mean performance of Group 1 was significantly higher than Group 2 across all seven positions. An analysis of simple within effects for each group indicated that there was a significant simple within effects for both groups. The Tukey (WSD) procedure for Group 1 revealed that there were significant differences between the following pairwise comparisons: (1) positions six and five with positions seven, three, two, and one; (2) positions four, seven, and three with positions two and one, and (3) position two with position one. For Group 2, the Tukey procedure indicated that there were significant differences between the following pairwise comparisons: (1) position five with positions six, three, seven, two, and one; (2) position four with positions three, seven, two, and one; (3) position six with positions seven, two, and one; (4) position three with positions two and one, and (5) position two with position one. All other pairwise comparisons for both groups were not significant.

In summary, three of the four hypotheses indicated a significant response by group interaction. Hypothesis three (one-second visual rate of presentation) was the one hypothesis retained. Significant between group differences favoring Group 1 were indicated across all seven positions for three of the dependent measures. For the one-second auditory rate of presentation, no significant difference was

indicated for position seven. Significant within group differences were indicated for each dependent measure. The graphic representation of the performance for the two groups indicated differences in performance between positions for each dependent measure.

Section II

This section reports the comparisons within and among three experimental groups (chunking, verbal stringing, and hawthorne) on the gain between pretesting and posttesting on four dependent measures. The four dependent variables (one-second auditory, two-second auditory, one-second visual, and two second visual conditions) are treated separately. In order to test the a priori hypotheses of no differences among experimental groups, a univariate analysis of variance was performed on the gain scores at each position for each dependent measure. To test the hypothesis of no differences among positions within a treatment group, a single-factor design with repeated measures was used to analyze the gain scores for each dependent measure. The analyses were calculated to the eighth decimal position, but the summary results have been rounded to the second decimal position for presentation in the tables.

One-Second Auditory Condition

The means and standard deviations of the gain score performances for the three experimental groups are contained in Table 22. Figure 9 represents a graphic representation of the experimental groups' performances across seven positions of the digit span. Variance-covariance matrices for the one-second auditory measure are contained

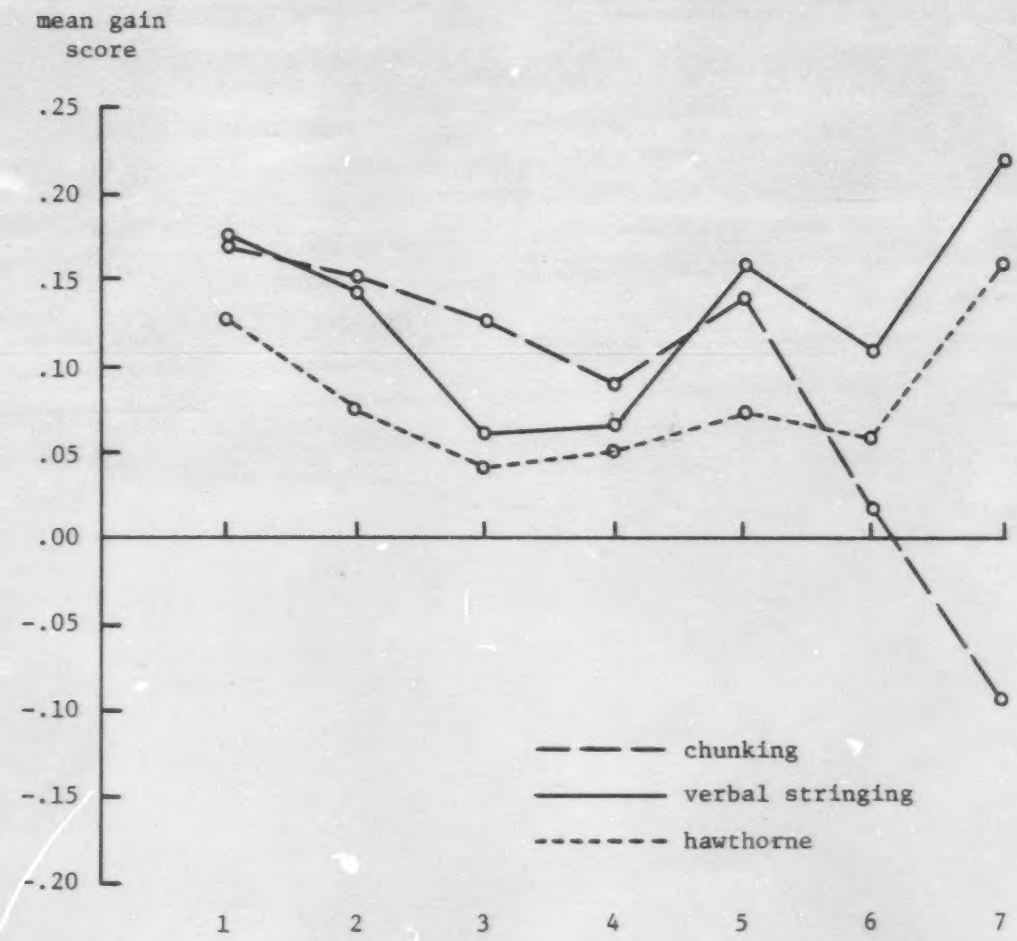

Figure 9. Mean gain scores for the chunking, verbal stringing, and hawthorne groups across seven positions at the one-second auditory condition.

Table 22

Means and standard deviations of the gain scores at each position for each group (n=10) for the one-second auditory condition

	Serial Position						
	1	2	3	4	5	6	7
Chunking (a_1)	$\bar{X}$=.17	$\bar{X}$=.15	$\bar{X}$=.13	$\bar{X}$=.09	$\bar{X}$=.14	$\bar{X}$=.01	$\bar{X}$=-.09
	S=.22	S=.16	S=.11	S=.11	S=.09	S=.11	S= .13
Verbal Stringing (a_2)	$\bar{X}$=.18	$\bar{X}$=.14	$\bar{X}$=.06	$\bar{X}$=.07	$\bar{X}$=.16	$\bar{X}$=.11	$\bar{X}$= .22
	S=.21	S=.15	S=.19	S=.14	S=.18	S=.18	S= .23
Hawthorne (a_3)	$\bar{X}$=.13	$\bar{X}$=.07	$\bar{X}$=.04	$\bar{X}$=.05	$\bar{X}$=.07	$\bar{X}$=.06	$\bar{X}$= .16
	S=.14	S=.11	S=.09	S=.11	S=.07	S=.12	S= .19

in Appendix B. Hypotheses five and six were concerned with the differences in performance for the one-second auditory condition.

Hypothesis Five

Hypothesis five was concerned with the differences in performance among the three experimental groups at each of the seven positions for the one-second auditory condition. Univariate analyses of variance were then performed on gain scores for each position to test differences among the three experimental groups. The results of the analysis for each position are treated separately.

Position One. Table 23 contains the summary of the analysis of variance for position one. The analysis revealed that there were no significant differences among the three experimental groups.

Table 23

Summary table for analysis of variance for between group effects at position one for hypothesis five

Source of Variation	SS	dF	MS	F
Between Groups	.01	2	.01	.15*
Error	1.03	27	.04	
Total	1.04	29		

*.05$F(2,27)=3.37$

Position Two. The results of the analysis of variance for position two are presented in Table 24. The analysis indicated that there were no significant differences among the three experimental groups.

Position Three. Table 25 contains the summary results of the analysis of variance for position three. The analysis revealed that there were no significant differences among the three experimental groups.

Position Four. The results of the analysis of variance for position four are contained in Table 26. The analysis revealed that there were no significant differences among the three experimental groups.

Position Five. Table 27 contains the summary results for the analysis of variance for position five. The analysis revealed that there were no significant differences among the three experimental groups.

Table 24

Summary table for analysis of variance for between group effects at position two for hypothesis five

Source of Variation	SS	dF	MS	F
Between Groups	.04	2	.02	1.00*
Error	.53	27	.02	
Total	.57	29	.02	

*$.05F(2,27)=3.37$

Table 25

Summary table for analysis of variance for between group effects at position three for hypothesis five

Source of Variation	SS	dF	MS	F
Between Groups	.05	2	.02	1.30*
Error	.48	27	.02	
Total	.53	29		

*$.05F(2,27)=3.37$

Table 26

Summary table for analysis of variance for between group effects at position four for hypothesis five

Source of Variation	SS	dF	MS	F
Between Groups	.01	2	.00	.25*
Error	.39	27	.01	
Total	.40	29		

*$.05F(2,27)=3.37$

Table 27

Summary table for analysis of variance for between group effects at position five for hypothesis five

Source of Variation	SS	dF	MS	F
Between Groups	.04	2	.02	1.33*
Error	.41	27	.02	
Total	.45	29		

*$.05F(2,27)=3.37$

Position Six. The results of the analysis of variance for position six are contained in Table 28. The analysis indicated that there were no significant differences among the three experimental groups.

Table 28

Summary table for analysis of variance for between group effects at position six for hypothesis five

Source of Variation	SS	dF	MS	F
Between Groups	.05	2	.03	1.44*
Error	.51	27	.02	
Total	.56	29		

*$.05F(2,27)=3.37$

Position Seven. Table 29 contains a summary of the analysis of variance for position seven. The analysis revealed that there was a significant between groups difference. The Tukey (WSD) procedure was then used with the appropriate mean square error term to test the difference between all pairs of means. Table 30 contains the results of this analysis. The Tukey procedure indicated that there were significant differences when comparing the performance of the chunking group with that of the verbal stringing and hawthorne groups. As can be noted, there was no significant difference between the performance of the verbal stringing and hawthorne groups.

Table 29

Summary table for analysis of variance for between group effects at position seven for hypothesis five

Source of Variation	SS	dF	MS	F
Between Groups	.54	2	.27	7.67*
Error	.95	27	.04	
Total	1.49	29		

*$.05^{F}(2,27)=3.37$

Table 30

Summary table for Tukey (WSD) procedure for between groups effect at position seven for hypothesis five

Order	a_1	a_3	a_2
a_1		**	**

*$.05^{q}(3,27)=2.50^{a}$

[a]Critical value expressed in t-statistic

Hypothesis Six

Hypothesis six was concerned with the differences in performance among positions for each group at the one-second auditory rate of presentation. A single-factor design with repeated measures was used to test differences among positions of each experimental group for hypothesis six. The results of these analyses for each group are treated separately.

Chunking Group (a_1). Table 31 contains the summary of the analysis of variance for the chunking group. The analysis revealed a significant difference between positions for the chunking group. The Tukey (WSD) procedure was then used to test the differences between all pairs of means. Since the homogeneity of variance could not be tested individual variances and covariances for each position were then used to calculate the appropriate t-statistics. Table 32 contains the summary results for the Tukey procedure. The analysis revealed that there were significant differences between the following pairwise comparisons: (1) position seven with positions three, five, two, and one, and (2) position six with position five.

Verbal Stringing (a_2). The results for the analysis of variance for the verbal stringing group are presented in Table 33 for hypothesis six. The analysis revealed that there was a significant within effect for positions within the verbal stringing group. The Tukey (WSD) procedure was then used to test the difference between all pairs of means. Since the homogeneity of variance between positions could not be computed, individual variances and covariances for each position were then used to calculate the appropriate t-statistics. Table 34 contains the summary for the Tukey procedure. The analysis revealed that there

Table 31

Summary table for analysis of variance for within effects for chunking group for hypothesis six

Source of Variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	.47	9	.52	
Within Subjects	1.25	60		
J (positions)	.54	6	.09	6.79*
residual	.71	54	.01	
Total	1.72	69		

*$.05F(6,54)=2.34$

Table 32

Summary table for Tukey (WSD) procedure for within effects for chunking group for hypothesis six

Order	7	6	4	3	5	2	1
7				**	**	**	**
6					**		

*$.05q(7,54)=3.10$[a]

[a]Critical value expressed in t-statistic

Table 33

Summary table for analysis of variance for within effects for verbal stringing group for hypothesis six

Source of Variation	SS	dF	MS	F
Between Subjects				
Subjects w. groups	1.40	9	.16	
Within Subjects	.92	60		
J (positions)	.19	6	.03	2.37*
Residual	.73	54	.01	
Total	2.32	69		

*$.05F(6,54)=2.34$

Table 34

Summary table for Tukey (WSD) procedure for within effect for verbal stringing group for hypothesis six

Order	3	4	6	2	5	1	7
3							**

*$.05q(6,54)=3.10$[a]

[a]Critical value expressed in t-statistic

was a significant difference between position three and position seven.

Hawthorne Group (a_3). Table 35 contains the results for the analysis of variance performed on the hawthorne group for hypothesis six. The analysis revealed that there were no significant differences among positions for the hawthorne group.

Table 35

Summary table for analysis of variance for within group effects for hawthorne group for hypothesis six

Source of Variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	.39	9	.04	
Within Subjects	.71	60		
J (positions)	.12	6	.02	1.87*
residual	.59	54	.01	
Total	1.10	69		

*$.05F(6,54)=2.34$

Two-Second Auditory Condition

The means and standard deviations of the gain score performances for the three experimental groups are contained in Table 36. Figure 10 represents a graphic illustration of the gain score performances of the three experimental groups. Appendix B contains the variance-covariance matrices for the two-second auditory condition. Hypotheses seven and

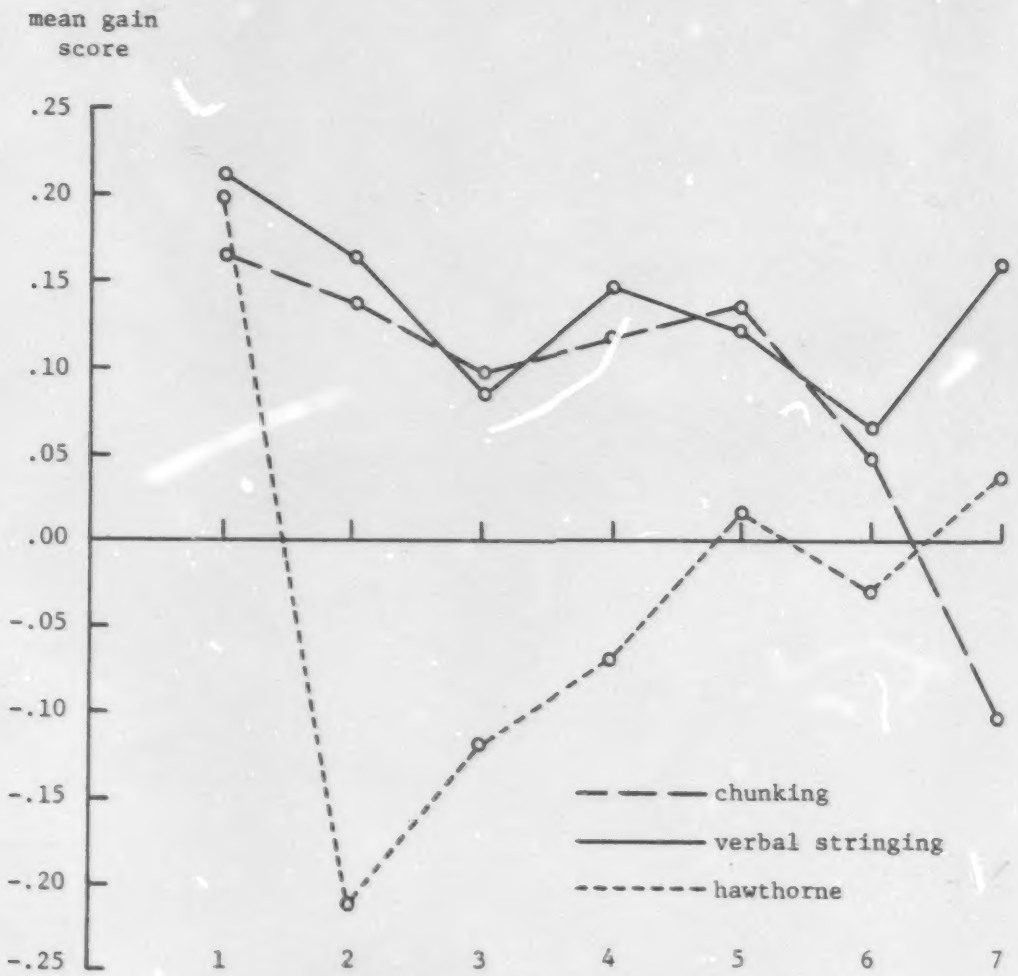

Figure 10. Mean gain scores for the chunking, verbal stringing, and hawthorne groups across seven positions at the two-second auditory condition.

Table 36

Means and standard deviations of gain score performances at each position for each group (n=10) for the two-second auditory condition

	Serial Position						
	1	2	3	4	5	6	7
chunking (a_1)	$\bar{X}$= .17	$\bar{X}$=.14	$\bar{X}$=.10	$\bar{X}$=.12	$\bar{X}$=.14	$\bar{X}$=.05	$\bar{X}$=-.10
	S= .20	S=.21	S=.14	S=.09	S=.10	S=.15	S= .21
verbal stringing (a_2)	$\bar{X}$= .21	$\bar{X}$=.17	$\bar{X}$=.09	$\bar{X}$=.15	$\bar{X}$=.13	$\bar{X}$=.07	$\bar{X}$= .16
	S= .19	S=.16	S=.16	S=.14	S=.15	S=.22	S= .23
hawthorne (a_3)	$\bar{X}$=-.20	$\bar{X}$=-.21	$\bar{X}$=-.12	$\bar{X}$=-.07	$\bar{X}$=.02	$\bar{X}$=-.03	$\bar{S}$= .04
	S= .17	S= .15	S= .18	S= .22	S=.10	X= .17	S= .22

eight were concerned with the differences in performance for the two-second auditory condition.

Hypothesis Seven

Hypothesis seven was concerned with the differences in performance among the three experimental groups at each of the seven positions for the two-second auditory condition. Univariate analysis of variance were then performed on the gain scores for each position to test differences among the three experimental groups. The results of the analysis for each position are treated separately.

Position One. Table 37 contains the summary for the analysis of variance used to test the between group differences at position one. The analysis indicated that there was a significant between groups

Table 37

Summary table for analysis of variance for between group effects at position one for hypothesis seven

Source of Variation	SS	dF	MS	F
Between Groups	1.01	2	.50	14.43*
Error	.94	27	.03	
Total	1.95	29		

*$.05F(2,27)=3.37$

effect at position one. The Tukey (WSD) procedure was then used with the appropriate mean square error term to test the difference between all pairs of means. Table 38 contains a summary of the results for the Tukey procedure. The analysis revealed that the chunking and verbal stringing groups' performances were significantly higher than that of the hawthorne group. There was no significant difference between the chunking and verbal stringing groups.

Position Two. The results for the analysis of variance at position two are presented in Table 39. The analysis indicated that there was a significant between groups effect. The Tukey (WSD) procedure was then used with the appropriate mean square error term to test the difference between all pairs of means; the results are reported in Table 38. The analysis revealed that the performance of both the chunking and verbal stringing groups were significantly higher than that of the hawthorne group. There was no significant difference between the chunking and verbal stringing groups.

Table 38

Summary table for Tukey (WSD) procedure for hypothesis seven

Position 1	Order	a_3	a_1	a_2
	a_3		**	**

Position 2	Order	a_3	a_1	a_2
	a_3		**	**

Position 3	Order	a_3	a_2	a_1
	a_3		**	**

Position 4	Order	a_3	a_1	a_2
	a_3		**	**

Position 7	Order	a_1	a_3	a_2
	a_1			**

*$.05^{q}(3,27)=2.50^{a}$

[a]Critical value expressed in t-statistic

Table 39

Summary table for analysis of variance for between group effects at position two for hypothesis seven

Source of variation	SS	dF	MS	F
Between Groups	.91	2	.46	15.03*
Error	.82	27	.03	
Total	1.73	29		

*.05$F(2,27)=3.37$

Position Three. The results for the analysis of variance at position three are presented in Table 40. The analysis revealed that there was a significant between groups effect. The Tukey (WSD) procedure was then used with the appropriate mean square error term to test the difference between all pairs of means, the results of which are reported in Table 38. The hawthorne group's performance was significantly lower than that of either the chunking or verbal stringing groups. No significant difference was indicated between the chunking and verbal stringing groups.

Position Four. The results for the analysis of variance at position four are presented in Table 41. The analysis indicated that there was a significant between groups effect. The Tukey (WSD) procedure was then used with the appropriate mean square error term to test the difference between all pairs of means, the results of which are contained in Table 38. The hawthorne group's performance was significantly lower than that of either the chunking or verbal stringing groups. No significant difference was indicated between the chunking and verbal stringing groups.

Table 40

Summary table for analysis of variance for between group effects at position three for hypothesis seven

Source of Variation	SS	dF	MS	F
Between Groups	.32	2	.16	7.08*
Error	.61	27	.02	
Total	.93	29		

*$.05^{F}(2,27)=3.37$

Table 41

Summary table for analysis of variance for between group effects at position four for hypothesis seven

Source of Variation	SS	dF	MS	F
Between Groups	.30	2	.15	5.93*
Error	.67	27	.02	
Total	.97	29		

*$.05^{F}(2,27)=3.37$

Position Five. Table 42 contains the summary for the analysis of variance used to test between group differences at position five. The analysis revealed that there was not a significant between groups effect.

Table 42

Summary table for analysis of variance for between group effects at position five for hypothesis seven

Source of Variation	SS	dF	MS	F
Between Groups	.08	2	.04	2.77*
Error	.39	27	.01	
Total	.47	29		

*.05$F(2,27)=3.37$

Position Six. The results for the analysis of variance at position six are presented in Table 43. The analysis revealed that there was not a significant between groups effect for position six.

Position Seven. Table 44 contains the summary for the analysis of variance used to test the between group differences at position seven. The analysis revealed that there was a significant between groups effect for position seven. The Tukey (WSD) procedure was then used with the appropriate mean square error term to test the difference between all pairs of means, the results of which are reported in Table 38. The performance of the chunking group was significantly lower than that of the verbal stringing group. All other pairwise comparisons were not significant.

Table 43

Summary table for analysis of variance for between group effects at position six for hypothesis seven

Source of Variation	SS	dF	MS	F
Between Groups	.06	2	.03	.85*
Error	.92	27	.03	
Total	.98	29		

*$.05F(2,27)=3.37$

Table 44

Summary table for analysis of variance for between group effects at position seven for hypothesis seven

Source of Variation	SS	dF	MS	F
Between Groups	.34	2	.17	3.57*
Error	1.29	27	.05	
Total	1.63	29		

*$.05F(2,27)=3.37$

Hypothesis Eight

Hypothesis eight was concerned with the differences in performance among positions for each group at the two-second auditory condition. A single-factor design with repeated measures was then performed to test within effects for each experimental group. The results of the analysis for each group are treated separately.

Chunking Group (a_1). Table 45 contains the summary for the analysis of variance of within effects for the chunking group. The analysis revealed a significant within effect. The Tukey (WSD) procedure was then used with the individual variances and covariances for each position to test the difference between all pairs of means; the results are reported in Table 46. There were significant differences between position seven and positions five and one. All other pairwise comparisons were found to be nonsignificant.

Table 45

Summary table for analysis of variance for within effects for chunking group for hypothesis eight

Source of variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	.51	9	.06	
Within Subjects	1.71	60		
J (positions)	.51	6	.09	3.85*
residual	1.20	54	.02	
Total	2.22	69		

*$.05F(6,54)=2.34$

Table 46

Summary table for Tukey (WSD) procedure for within effect for chunking group for hypothesis eight

Order	7	6	3	4	5	2	1
7					**		**

*.05^{q}(7,54)=3.10[a]

[a]Critical value expressed as t-statistic

Verbal Stringing Group (a_2). The results for the analysis of variance for within effects of the verbal stringing group are presented in Table 47. The analysis indicated that there was not a significant within effect for the verbal stringing group.

Hawthorne Group (a_3). Table 48 contains the summary for the analysis of variance of within effects for the hawthorne group. The analysis revealed that there was a significant within effect for the hawthorne group. The Tukey (WSD) procedure was then used with the individual variances and covariances for each position to test the difference between all pairs of means; the results are reported in Table 49. There were significant differences between position five and positions two and one.

One-Second Visual Condition

The means and standard deviations of the gain score performances for the three experimental groups are contained in Table 50. Figure 11 represents a graphic representation of the experimental groups' performances across all seven positions of the digit span. Variance-covariance

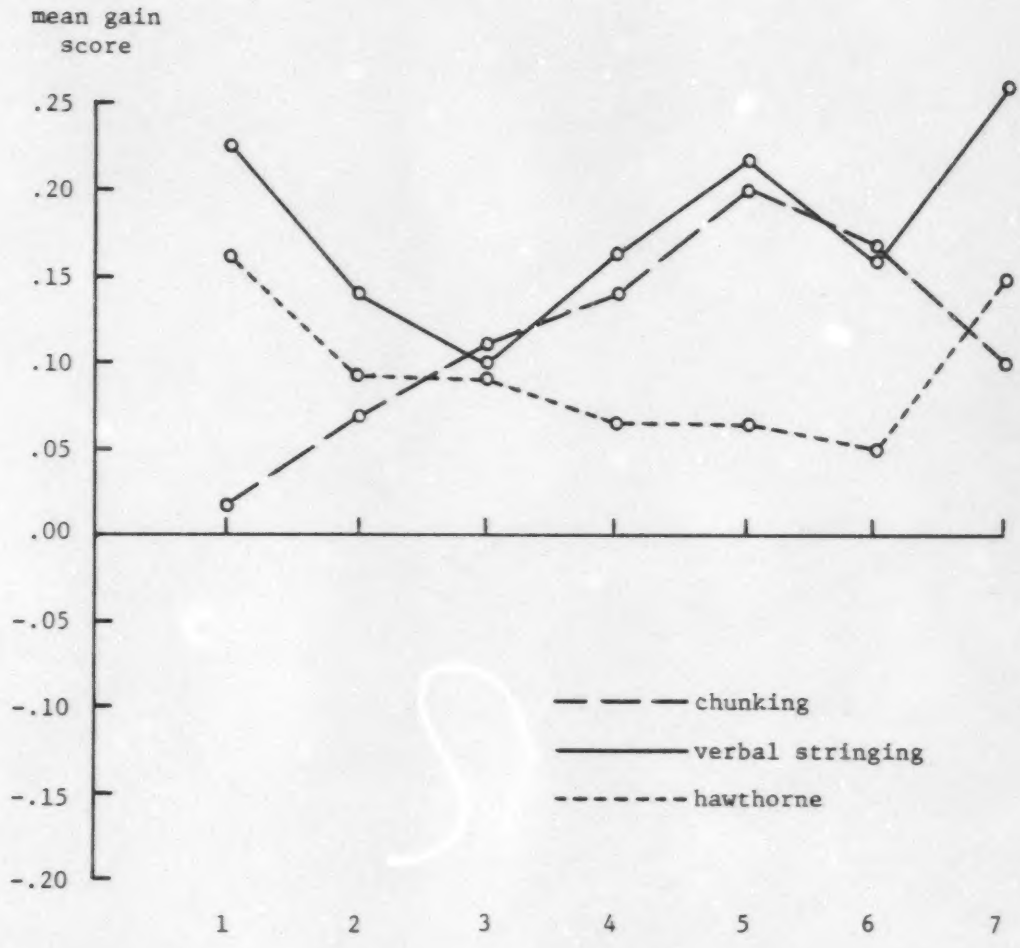

Figure 11. Mean gain scores for the chunking, verbal stringing, and hawthorne groups across seven positions at the one-second visual condition.

Table 47

Summary table for analysis of variance for within effects for verbal stringing group for hypothesis eight

Source of Variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	1.24	9	.14	
Within Subjects	.95	60		
J (positions)	.13	6	.02	1.407*
residual	.82	54	.02	
Total	2.19	69		

*$.05F(6,54)=2.34$

Table 48

Summary table for analysis of variance for within effects for the hawthorne group for hypothesis eight

Source of Variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	.52	9	.06	
Within Subjects	1.96	60		
J (positions)	.61	6	.10	4.06
residual	1.35	54	.03	
Total	2.48	69		

*$.05F(6,54)=2.34$

Table 49

Summary table for Tukey (WSD) procedure for within effect for hawthorne group for hypothesis eight

Order	2	1	3	4	6	5	7
2						**	
1						**	

*.05^{q}(7,54)=3.10^{a}

[a]Critical value expressed as t-statistic

Table 50

Means and standard deviations of gain score performances at each position for each group (n=10) for the one-second visual condition

	Serial Position						
	1	2	3	4	5	6	7
chunking (a_1)	$\bar{X}$=.12	$\bar{X}$=.07	$\bar{X}$=.11	$\bar{X}$=.14	$\bar{X}$=.20	$\bar{X}$=.17	$\bar{X}$=.10
	S=.28	S=.24	S=.17	S=.16	S=.15	S=.22	S=.19
verbal stringing (a_2)	$\bar{X}$=.23	$\bar{X}$=.14	$\bar{X}$=.10	$\bar{X}$=.16	$\bar{X}$=.22	$\bar{X}$=.16	$\bar{X}$=.26
	S=.24	S=.27	S=.15	S=.08	S=.16	S=.11	S=.18
hawthorne (a_3)	$\bar{X}$=.16	$\bar{X}$=.09	$\bar{X}$=.09	$\bar{X}$=.07	$\bar{X}$=.07	$\bar{X}$=.05	$\bar{X}$=.15
	S=.20	S=.12	S=.08	S=.05	S=.10	S=.16	S=.14

matrices are contained in Appendix B for the one-second visual condition. Hypotheses nine and ten were concerned with differences in performance for the one-second visual condition.

Hypothesis Nine

Hypothesis nine was concerned with the differences in performance among the three experimental groups at each of the seven positions for the one-second visual condition. Univariate analyses of variance were then performed on gain scores for each position to test differences among the three experimental groups. The results of the analysis for each position are treated separately.

Position One. Table 51 contains the summary for the analysis of variance used to test between group differences at position one. The analysis indicated that there was not a significant between groups effect.

Table 51

Summary table for analysis of variance for between group effects at position one for hypothesis nine

Source of Variation	SS	dF	MS	F
Between Groups	.21	2	.11	1.80*
Error	1.60	27	.06	
Total	1.81	29		

*$.05F(2,27)=3.37$

Position Two. The results for the analysis of variance to test between group differences at position two are presented in Table 52. The analysis revealed that there was not a significant between groups effect.

Table 52

Summary table for analysis of variance for between group effects at position two for hypothesis nine

Source of Variation	SS	dF	MS	F
Between Groups	.03	2	.01	.29*
Error	1.32	27	.05	
Total	1.35	29		

*$.05F(2,27)=3.37$

Position Three. Table 53 contains the summary for the analysis of variance used to test the between groups difference at position three. The analysis indicated that there was not a significant between groups effect.

Position Four. The results for the analysis of variance to test between group differences at position four are presented in Table 54. The analysis indicated that there was not a significant between group effects.

Position Five. Table 55 contains the summary for the analysis of variance used to test the between group differences at position five. The analysis revealed that there was not a significant between groups effect.

Table 53

Summary table for analysis of variance for between group effects at position three for hypothesis nine

Source of Variation				F
Between Groups	.00	2	.00	.07*
Error	.52	27	.02	
Total	.52	29		

*$.05F(2,27)=3.37$

Table 54

Summary table for analysis of variance for between group effects at position four for hypothesis nine

Source of Variation	SS	dF	MS	F
Between Groups	.04	2	.02	1.83*
Error	.31	27	.01	
Total	.35	29		

*$.05F(2,27)=3.37$

Table 55

Summary table for analysis of variance for between group effects at position five for hypothesis nine

Source of Variation	SS	dF	MS	F
Between Groups	.13	2	.07	3.24*
Error	.54	27	.02	
Total	.67	29		

*.05$F(2,27)=3.37$

Position Six. The results for the analysis of variance to test the between group differences at position six are presented in Table 56. The analysis indicated that there was not a significant between groups effect.

Position Seven. Table 57 contains the summary for the analysis of variance used to test the between group differences at position seven. The analysis indicated that there was not a significant between groups effect.

Hypothesis Ten

Hypothesis ten was concerned with the differences in performances among positions for each group for the one-second visual condition. A single-factor design with repeated measures was then used to test within effects for each experimental group. The results of the analysis for each group are treated separately.

Chunking Group (a_1). Table 58 contains the summary for the analysis of variance of within effects for the chunking group. The

Table 56

Summary table for analysis of variance for between group effects at position six for hypothesis nine

Source of Variation	SS	dF	MS	F
Between Groups	.09	2	.05	1.58*
Error	.79	27	.03	
Total	.88	29		

*$.05^{F}(2,27)=3.37$

Table 57

Summary table for analysis of variance for between group effects at position seven for hypothesis nine

Source of Variation	SS	dF	MS	F
Between Groups	.13	2	.06	2.24*
Error	.78	27	.03	
Total	.91	29		

*$.05^{F}(2,27)=3.37$

Table 58

Summary table for analysis of variance for within effects for chunking group for hypothesis ten

Source of Variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	1.24	9	.14	
Within Subjects	1.67	60		
J (positions)	.23	6	.04	1.42*
residual	1.44	54	.03	
Total	2.91	69		

*$.05F(6,54)=2.34$

analysis revealed that there was not a significant within effects for the chunking group.

Verbal Stringing Group (a_2). The results for the analysis of variance for within effects of the verbal stringing group are presented in Table 59. The analysis revealed that there was not a significant within effects for the verbal stringing group.

Hawthorne Group (a_3). Table 60 contains the summary for the analysis of variance of within effects for the hawthorne group. The analysis indicated that there was not a significant within effects for the hawthorne group.

Two-Second Visual Condition

The means and standard deviations of the gain score performances for the three experimental groups are contained in Table 61. Figure 12

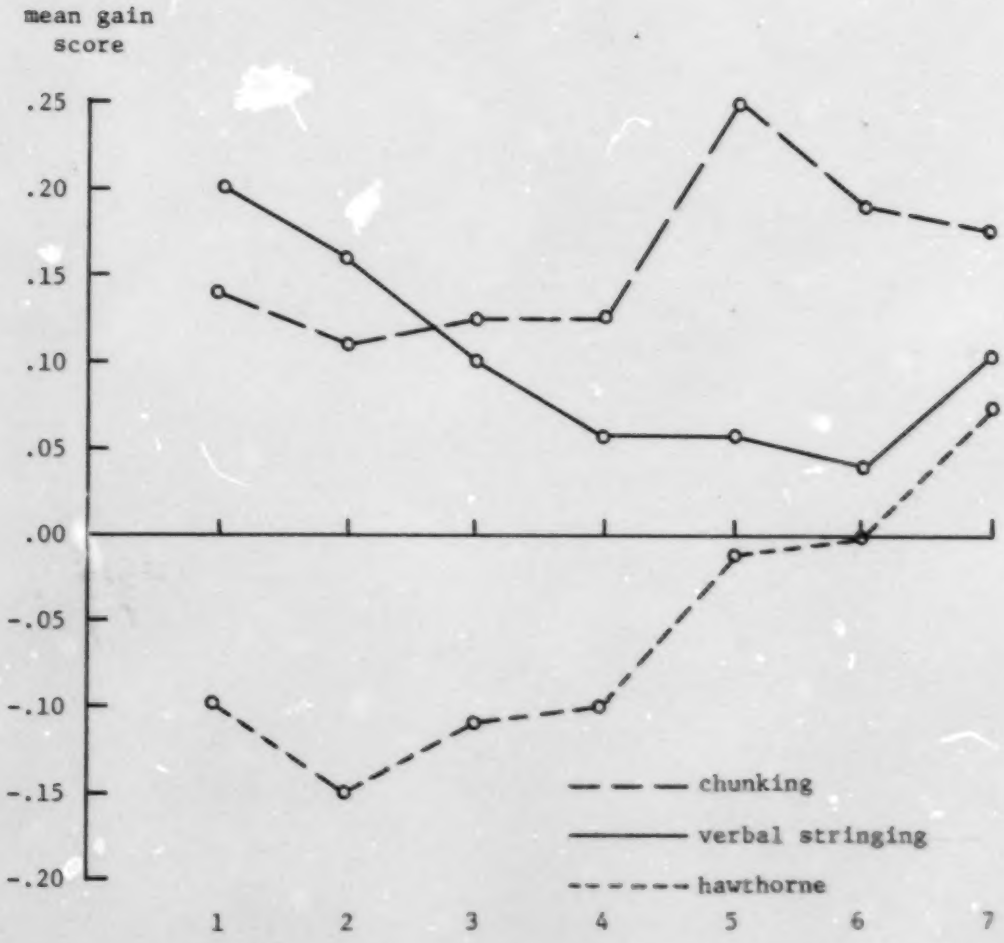

Figure 12. Mean gain scores for the chunking, verbal stringing, and hawthorne groups across seven positions at the two-second visual condition.

Table 59

Summary table for analysis of variance for within effects for verbal stringing group for hypothesis ten

Source of Variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	1.01	9	.11	
Within Subjects	1.25	60		
J (positions)	.19	6	.03	1.59*
residual	1.06	54	.02	
Total	2.26	69		

*$.05F(6,54)=2.34$

Table 60

Summary table for analysis of variance for within effects for hawthorne group for hypothesis ten

Source of Variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	.31	9	.03	
Within Subjects	.89	60		
J (positions)	.10	6	.02	1.14*
residual	.79	54	.01	
Total	1.20	69		

*$.05F(6,54)=2.34$

Table 61

Means and standard deviations of gain score performances at each position for each group (n=10) for the two-second visual condition

	Serial Position						
	1	2	3	4	5	6	7
chunking (a_1)	$\bar{X}$=.14	$\bar{X}$=.11	$\bar{X}$=.13	$\bar{X}$=.13	$\bar{X}$=.25	$\bar{X}$=.19	$\bar{X}$=.18
	S=.20	S=.19	S=.20	S=.21	S=.17	S=.18	S=.20
verbal stringing (a_2)	$\bar{X}$=.20	$\bar{X}$=.16	$\bar{X}$=.10	$\bar{X}$=.06	$\bar{X}$=.06	$\bar{X}$=.04	$\bar{X}$=.11
	S=.15	S=.09	S=.18	S=.19	S=.10	S=.11	S=.15
hawthorne (a_3)	$\bar{X}$=-.10	$\bar{X}$=-.15	$\bar{X}$=-.11	$\bar{X}$=-.10	$\bar{X}$=-.01	$\bar{X}$=.00	$\bar{X}$=.08
	S= .19	S= .17	S= .20	X= .19	S= .13	S=.18	S=.16

represents a graphic representation of the experimental groups' performances across all seven positions of the digit span. Variance-covariance matrices are presented in Appendix B for the two-second visual condition. Hypotheses eleven and twelve were concerned with differences in performance for the two-second visual condition.

Hypothesis Eleven

Hypothesis eleven was concerned with differences in performance among the three experimental groups at each of the seven positions for the two-second visual condition. Univariate analysis of variance were then performed on gain scores for each position to test differences among the three experimental groups. The results of the analysis for each position are treated separately.

Position One. Table 62 contains the summary for the analysis of variance used to test between group differences at position one for hypothesis eleven. The analysis revealed that there was a significant between groups effect. The Tukey (WSD) procedure was then used with the appropriate mean square error term to test the difference between all pairs of means; the results are reported in Table 69. The analysis indicated that the mean performances of the chunking and verbal stringing group were both significantly higher than that of the hawthorne group. There was no significant difference found between the chunking and verbal stringing groups.

Table 62

Summary table for analysis of variance for between group effects at position one for hypothesis eleven

Source of Variation	SS	dF	MS	F
Between Groups	.52	2	.26	7.77*
Error	.91	27	.03	
Total	1.43	29		

*$.05F(2,27)=3.37$

Position Two. The reqults for the analysis of variance for between groups effect at position two are presented in Table 63. The analysis revealed that there was a significant between groups effect. The Tukey (WSD) procedure was then used with the appropriate mean square error term to test the difference between all pairs of means;

Table 63

Summary table for analysis of variance for between group effects at position two for hypothesis eleven

Source of Variation	SS	dF	MS	F
Between Groups	.55	2	.27	10.82*
Error	.68	27	.03	
Total	1.23	29		

*.05$F(2,27)=3.37$

the results are reported in Table 69. The pairwise comparison procedure indicated that the mean performances of the chunking and verbal stringing groups were both significantly higher than that of the hawthorne group. No significant difference was found between the chunking and verbal stringing groups.

Position Three. Table 64 contains the summary for the analysis of variance used to test between group differences at position three for hypothesis eleven. The analysis indicated that there was a significant between groups effect at position three. The Tukey (WSD) procedure was then used with the appropriate mean square error term to test the difference between all pairs of means; the results are presented in Table 69. The analysis revealed that the chunking group's mean performance was significantly higher than the performance of the hawthorne group. All other pairwise comparisons were nonsignificant.

Position Four. The results for the analysis of variance used to test between groups effect at position four are presented in Table 65 for hypothesis eleven. The analysis indicated that there was a

Table 64

Summary table for analysis of variance for between group effects at position three for hypothesis eleven

Source of Variation	SS	dF	MS	F
Between Groups	.33	2	.16	4.40*
Error	1.01	27	.04	
Total	1.34	29		

*$.05F(2,27)=3.37$

Table 65

Summary table for analysis of variance for between group effects at position four for hypothesis eleven

Source of Variation	SS	dF	MS	F
Between Groups	.29	2	.15	3.77*
Error	1.05	27	.04	
Total	1.34	29		

*$.05F(2,27)=3.37$

significant between groups effect. The Tukey (WSD) procedure was then used with the appropriate mean square error term to test the difference between all pairs of means, the results of which are reported in Table 69. The Tukey procedure revealed that the mean performance of the chunking group was significantly higher than the hawthorne group's performance. No significant differences were found for the remaining pairwise comparisons.

Position Five. Table 66 contains the summary for the analysis of variance used to test between group differences at position five. The analysis revealed that there was a significant between groups effect. The Tukey (WSD) procedure was then used with the appropriate mean square error term to test the difference between all pairs of means, the results of which are reported in Table 69. The Tukey procedure indicated that the chunking group's performance was significantly higher than the performance for either the verbal stringing or hawthorne groups. No significant difference was found between the verbal stringing and hawthorne groups.

Table 66

Summary table for analysis of variance for between group effects at position five for hypothesis eleven

Source of Variation	SS	dF	MS	F
Between Groups	.37	2	.18	10.12*
Error	.49	27	.02	
Total	.86	29		

*$.05F(2,27)=3.37$

Position Six. Table 67 contains the summary for the analysis of variance used to test between group differences at position six. The analysis revealed that there was a significant between groups effect. The Tukey (WSD) procedure was then used with the appropriate mean square error term to test the difference between all pairs of means, the results of which are reported in Table 69. The analysis indicated that the mean performance for the chunking group was significantly higher than either the hawthorne or verbal stringing groups. No significant difference was found between the verbal stringing and hawthorne groups.

Table 67

Summary table for analysis of variance for between group effects at position six for hypothesis eleven

Source of Variation	SS	dF	MS	F
Between Groups	.20	2	.10	3.88*
Error	.69	27	.03	
Total	.89	29		

*$.05F(2,27)=3.37$

Position Seven. The results for the analysis of variance used to test between group differences at position seven are presented in Table 68. The analysis indicated that there was not a significant between groups effect at position seven.

Table 68

Summary table for analysis of variance for between group effects at position seven for hypothesis eleven

Source of Variation	SS	dF	MS	F
Between Groups	.05	2	.03	.91*
Error	.81	27	.03	
Total	.86	29		

*$.05F(2,27)=3.37$

Hypothesis Twelve

Hypothesis twelve was concerned with the differences in performance among positions for each group at the two-second visual condition. A single-factor design with repeated measures was then used to test within effects for each experimental group. The results of the analysis for each group are treated separately.

Chunking Group (a_1). Table 70 contains the summary for the analysis of variance of within effects for the chunking group. The analysis revealed that there was not a significant within effect for the chunking group.

Verbal Stringing Group (a_2). The results for the analysis of variance of within effects for the verbal stringing group are reported in Table 71. The analysis indicated that there was not a significant within effect for the verbal stringing group.

Hawthorne Group (a_3). Table 72 contains the summary for the analysis of variance of within effects for the hawthorne group. The analysis revealed that there was a significant within effect for the

Table 69

Summary table for Tukey (WSD) procedure for between group effects for hypothesis eleven

Position 1	Order	a_3	a_1	a_2
	a_3		**	**
Position 2	**Order**	a_3	a_1	a_2
	a_3		**	**
Position 3	**Order**	a_3	a_2	a_1
	a_3			**
Position 4	**Order**	a_3	a_2	a_1
	a_3			**
Position 5	**Order**	a_3	a_2	a_1
	a_3			**
	a_2			**
Position 6	**Order**	a_3	a_2	a_1
	a_3			**

*$.05^q(3,27)=2.50^a$

[a]Critical value expressed in t-statistic

Table 70

Summary table for analysis of variance for within effects for chunking group for hypothesis twelve

Source of Variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	1.67	9	.19	
Within Subjects	.80	60		
J (positions)	.14	6	.02	1.92*
residual	.66	54	.01	
Total	2.47	69		

*$.05F(6,54)=2.34$

Table 71

Summary table for analysis of variance for within effects for verbal stringing group for hypothesis twelve

Source of Variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	.37	9	.04	
Within Subjects	1.15	60		
J (positions)	.20	6	.03	1.84*
residual	.95	54	.02	
Total	1.52	69		

*$.05F(6,54)=2.34$

Table 72

Summary table for analysis of variance for within effects for hawthorne group for hypothesis twelve

Source of Variation	SS	dF	MS	F
Between Subjects				
subjects w. groups	.68	9	.08	
Within Subjects	1.70	60		
J (positions)	.41	6	.07	2.83*
residual	1.29	54	.02	
Total	2.38	69		

*$.05^{F}(6,54)=2.34$

hawthorne group. The Tukey (WSD) procedure was then used with individual variances and covariances to test the difference between all pairs of means; the results are reported in Table 73. The Tukey procedure indicated that the following pairwise differences were significant: (1) position two when compared to position five, and (2) position six when compared to position seven. The remaining pairwise comparisons were nonsignificant.

Table 73

Summary table for Tukey (WSD) procedure for within effect for hawthorne group for hypothesis twelve

Order	2	3	4	1	5	6	7
2					**		
6							**

*.05^{q}(7,54)=3.10^{a}

[a]Critical value expressed as t-statistic

Summary

Hypotheses five through twelve were concerned with posttest performances of the three experimental groups (chunking, verbal stringing, and hawthorne) on the four dependent measures. The summary for each hypothesis is presented separately.

Hypothesis Five. Hypothesis five was concerned with between group differences at each position for the one-second auditory rate of presentation. Univariate analyses of variance indicated that there

were no significant between groups effects for positions one through six. A significant between groups effect was revealed at position seven for hypothesis five. The Tukey (WSD) procedure indicated that the chunking group's performance was significantly lower than either the verbal stringing or hawthorne groups.

Hypothesis Six. Hypothesis six was concerned with between position differences for each group at the one-second auditory rate of presentation. A single-factor design with repeated measures was used to test within effects for each group. The analysis revealed that there was a significant within effect for the chunking group. The Tukey (WSD) procedure indicated that the following pairwise comparisons were significant: (1) position seven with positions three, five, two, and one, and (2) position six with position five. The analysis performed on the verbal stringing group indicated that there was a significant within effect for hypothesis six. The Tukey (WSD) procedure revealed that position three was significantly lower than position seven. The hypothesis of no differences among positions for the hawthorne group was retained.

Hypothesis Seven. Hypothesis seven was concerned with between group differences at each position for the two-second auditory rate of presentation. Univariate analyses of variance revealed that there was a significant between groups effect for position one through four. The Tukey (WSD) procedure revealed that there was no significant difference between the chunking and verbal stringing groups for position one through four, but both groups were significantly higher than the hawthorne group. For positions five and six, no significant between groups effect was indicated. For position seven, a significant between groups

effect was revealed. The Tukey (WSD) procedure indicated that the verbal stringing group's performance was significantly higher than that of the chunking group with no significant differences indicated between the other pairwise comparisons.

Hypothesis Eight. *Hypothesis eight was concerned with between* position differences for each group at the two-second auditory rate of presentation. A single-factor design with repeated measures was used to test within effects for each group. The analysis indicated that there was a significant within effect for the chunking group. The Tukey (WSD) procedure indicated that the following pairwise comparisons were significant: (1) position seven with position one, and (2) position five with position one. The hypothesis of no difference between positions for the verbal stringing group was retained. The analysis of within effects for the hawthorne group indicated a significant within effect for hypothesis eight. The Tukey (WSD) procedure revealed that positions two and one were significantly lower than position five.

Hypothesis Nine. Hypothesis nine was concerned with between group differences for each position at the one-second visual rate of presentation. Univariate analyses of variance revealed that there were no significant between groups effects for positions one through seven. The hypothesis of no differences among experimental groups at the one-second visual rate of presentation was retained.

Hypothesis Ten. Hypothesis ten was concerned with between position differences for each group at the one-second visual rate of presentation. A single-factor design with repeated measures was used to analyze within effects for each experimental group. The analyses indicated that there were no significant within effects for the three experimental groups.

Hypothesis Eleven. Hypothesis eleven was concerned with between group differences for each position at the two-second visual rate of presentation. Univariate analyses of variance indicated that there were significant between groups effects for positions one and two. The Tukey (WSD) procedure revealed that the mean performance of the hawthorne group was significantly lower than that of either the chunking or verbal stringing groups for positions one and two. No significant difference was indicated between the chunking and verbal stringing groups for these positions. For positions three and four, a significant between effect was indicated in the analysis. The Tukey (WSD) procedure revealed that the mean performance of the chunking group was significantly higher than that of the hawthorne group with no other significant differences between groups. For position five, a significant between groups effect was indicated in the analysis. The Tukey (WSD) procedure indicated that the performances of both the verbal stringing and hawthorne groups were significantly lower than that of the chunking group. No significant difference was found between the verbal stringing and hawthorne groups. For position six, a significant between groups effect was revealed in the analysis. The Tukey (WSD) procedure indicated that the mean performance of the hawthorne group was significantly lower than that of the chunking group with no other significant differences indicated. No significant between groups effect was indicated at position seven for hypothesis eleven.

Hypothesis Twelve. Hypothesis twelve was concerned with between position differences for each experimental group at the two-second auditory rate of presentation. A single-factor design with repeated measure was used to analyze the within effects for each experimental

group. No significant within effects were indicated in the analyses for the chunking and verbal stringing groups. There was a significant within effects revealed in the analysis for the hawthorne group. The Tukey (WSD) procedure revealed that the following pairwise comparisons were significant: (1) position two with position five, and (2) position six with position seven.

Overall, the chunking and verbal stringing treatments produced significant differences at twelve positions of a possible twenty-eight. The positions most consistently affected by training were positions one through four. These four positions indicated significant differences for both the auditory and visual two-second conditions.

Chapter V

DISCUSSION

This chapter contains an interpretative discussion of the results for both experiments, the conclusions, and the limitations and implications of this study. The discussion of results are treated in two sections corresponding to the two experiments performed in this study.

Pretest Discussion

Four hypotheses were considered in the pretest experiment comparing SPC performances between learning disabled children and normal children in two modalities with two different presentation rates. Three of the four hypotheses were rejected; the SPC profile analyses for the auditory one-second and two-second presentation rates, and the SPC profile analysis for the two-second presentation rates revealed significant response-by-group interactions. The SPC profile analysis for the visual one-second presentation rate indicated that the profiles for the two groups were parallel.

Although the SPCs were not parallel in three of the four conditions, both an inspection of the profiles for the two groups under the four conditions and an inspection of the pattern of the significant within group differences clearly indicate primacy and recency effects for learning disabled and normal children. The middle positions (four and five) were consistently demonstrated to be the most difficult

recall items for both groups. Therefore, based on Ellis's multi-process memory model (1970) learning disabled children are rehearsing primacy items, although their rehearsals do not produce the same level of recall. Learning disabled children's performances in recency items indicated that they do employ primary memory to hold stimuli although less efficiently than the normal children.

The overall performances of the learning disabled children were qualitatively similar to but quantitatively lower than the normal children. If the learning disabled children's inadequate STM were primarily a perceptual store deficiency, then recency effects would not be reflected in their SPC performance (Figure 13). If inadequate STM were primarily a rehearsal strategy deficiency, then the SPC performance for learning disabled children would not indicate primacy effects (Figure 14). The results of this experiment clearly indicate that learning disabled children exhibit a quantitative inefficiency in both primary and secondary memory.

The relative inefficiency in the recall performance of the learning disabled children did not appear to be equal across the SPCs. Figures 5 through 8 consistently reflect disproportionate differences between learning disabled and normal children. The relative distances were graphically more pronounced at the primacy and middle positions. The t values contained in Tables 3, 9, and 17 were consistently lower for the recency items. The statistical nonsignificance at position seven for hypothesis one provides additional evidence to suggest that learning disabled children exhibited greater inefficiency in secondary memory than primary memory with respect to normal children.

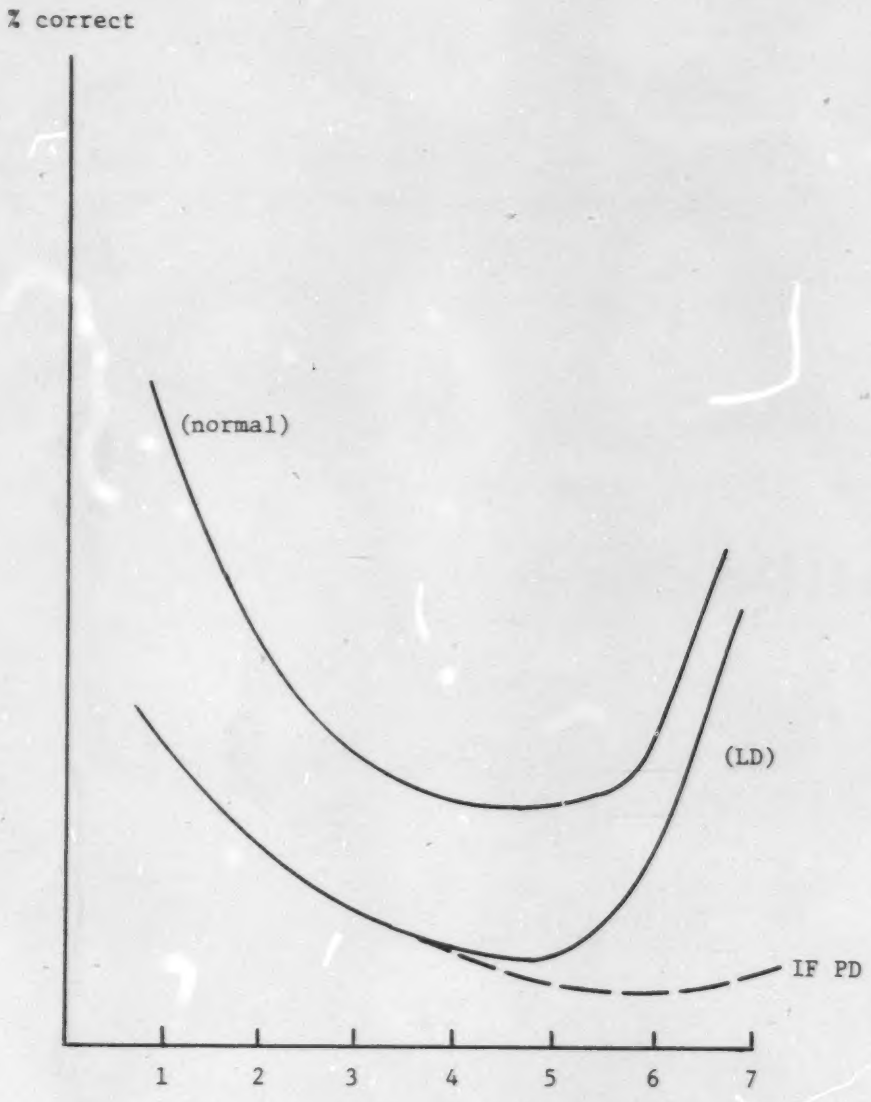

Figure 13. Hypothetical SPC for perceptual dysfunction in LD children.

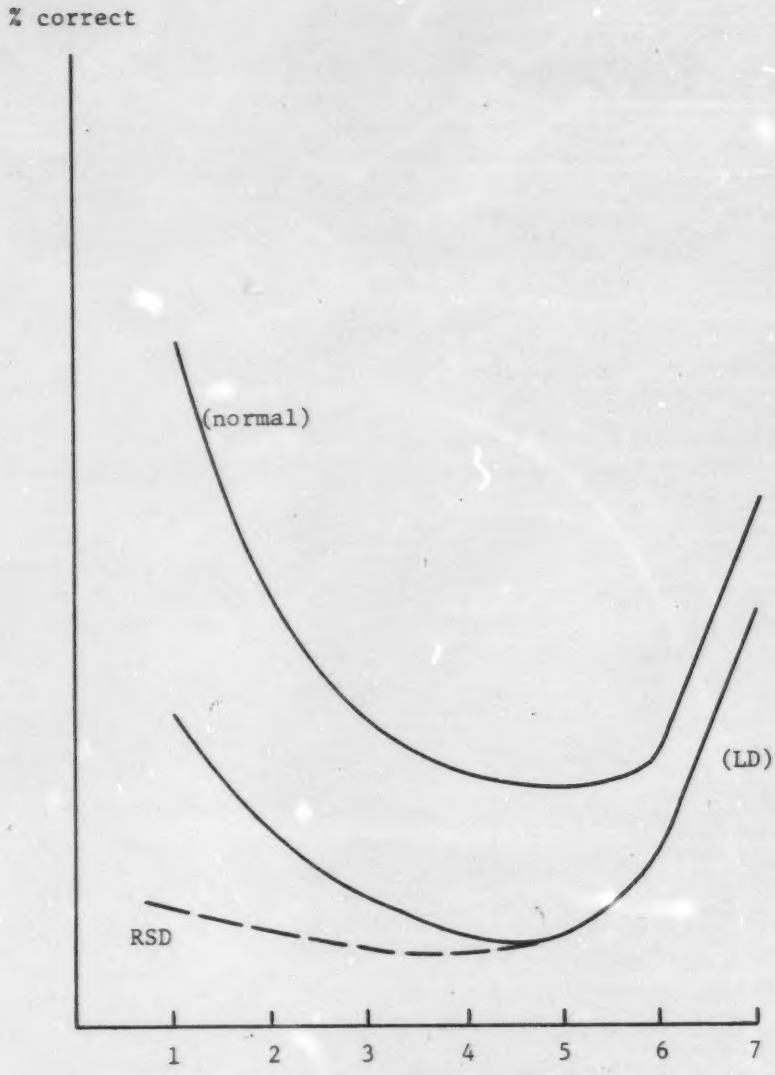

Figure 14. Hypothetical SPC for rehearsal strategy deficiency in LD children.

The quantitatively depressed SPC performance for learning disabled children may be explained by a number of interpretations. The primacy performance clearly indicated that learning disabled children employ rehearsal strategies although at a lower level than normal children. The poorer recency performance, on the other hand, may be explained with a number of plausible alternatives, e.g., attentional deficit, perceptual deficit or an interference between secondary and primary memory through the feedback mechanism.

Posttest Discussion

Eight hypotheses were considered in the second experiment comparing the training effects of different encoding strategies with learning disabled children. The SPC performances for the three experimental groups (chunking, verbal stringing, and hawthorne) were evaluated across two modalities with two different rates of presentation. Hypotheses nine and ten concerning the between and within group effects for the one-second visual presentation were retained. The other six hypotheses concerning the auditory one- and two-second rates and the visual two-second rate were rejected.

Three general trends were observed in the posttest analyses. The verbal stringing group's performance was significantly higher than the chunking group in recency performance for the auditory one- and two-second rates of presentation. The auditory mode of input seemed to interfere with the chunking group by requiring an additional recoding process of the stimulus items. The presentation rate may not have provided sufficient time for this strategy to be effective at the recency segment of the SPC. The additional requirement to recode the

auditory input served to interfere with the primary memory store since chunking organizes the input immediately at presentation. The verbal stringing does not require the recoding of input so that stimulus items remain intact during their rehearsal. Recency items for the verbal stringing were not altered at presentation thereby enabling the verbal stringing group's employment of primary memory store to retain these items.

The chunking group's performance was consistently more effective than the verbal stringing group for the visual two-second presentation. During visual presentation, the chunking condition requires less recoding of the stimulus items to organize into chunks. For example, if the sequence ". . . 2-1-3-6" is presented visually, the subject can code the "2" as "20" and upon the presentation of "1" completes the chunk as "21." On the other hand with the verbal stringing strategy, the subject rehearses the sequence as "two, two-one. . . ."

The verbal stringing and chunking groups were significantly higher than the hawthorne group at positions one through four for both two-second presentation rates. The significant between group differences primarily occurred as a result of the two rehearsal groups maintaining their level of performance for the one-second presentations while the hawthorne group's performance substantially diminished. The hawthorne group may have attempted to employ their one-second strategies to the increased time intervals which resulted in an inefficient application of the time available for rehearsal. The unused rehearsal time may have reduced the stability of the rehearsal strategies.

The rehearsal training did not produce differential gains in SPC performance. It was hypothesized that the gain score improvement would be reflected primarily in the primacy performance. The failure to produce this effect may have been due to a ceiling effect occurring in primacy performance. The failure to produce this effect may have been due to a ceiling effect occurring in primacy performance. The differential performance was not manifested because the subjects' performance could not be quantitatively improved beyond a certain level of recall performance.

The duration of the training phase may not have provided sufficient time for the learning disabled children to adopt a new rehearsal strategy. The forced mediation may not have produced the desired effects due to interference from the subjects' spontaneous rehearsal strategies. An optimal match between the subjects' rehearsal strategies and the instruction may have reflected a more pronounced gain in recall performance at the primacy segment, although practice with some strategy keeps the subject using a strategy. Practice in STM tasks appeared to have a facilitative effect in recall performance.

Conclusions

It was concluded that the overall performances of learning disabled children in STM were qualitatively similar to but quantitatively lower than normal children. Secondary memory for learning disabled children was disproportionately more inefficient than primary memory with respect to normal children.

The training of rehearsal strategies did not produce a significant differential improvement in primacy performance. It was concluded

that practice with some strategy keeps the subject using a strategy during longer intervals of presentation. Chunking appeared to be a more effective strategy when used to organize slower presented visual stimuli whereas verbal stringing appeared to be more effective for rehearsal of auditory stimuli during both presentation rates.

Limitations

Since the selection of learning disabled children was predicated on the Pennsylvania regulations mandating classroom admission criteria, generalization of these findings beyond such a population should be made with great care. In addition, caution should be used in attempting to generalize these findings to learning disabled children outside the age range of the subjects in this study.

The findings may not be applicable to STM tasks requiring different stimulus materials or employing different time parameters in their presentation rates.

Finally, generalizability of these findings using different methodology, e.g., the probed-recall technique, should be made with great care.

Implications

The mixed results found in this study suggest several questions which need to be investigated. First, future studies should investigate the effects of different stimuli, different "supraspan lengths," and varied time parameters to determine if the performance between normal and learning disabled children reflects the findings of this study.

Second, an attempt should be made to investigate spontaneous rehearsal strategies used by learning disabled children and to maximize instruction in rehearsal training by matching it to the child's rehearsal strategy.

Third, an attempt should be made to investigate the performance of learning disabled children across different STM tasks such as free recall and probed-recall to evaluate whether learning disabled children employ the same strategies independent of the requirements for the task.

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APPENDIX A

Variance-covariance Matrices for Pretest Analyses

Variance-covariance matrices for hypothesis one

Group 1 (normal)						
.0493	.0414	.0340	.0260	.0250	.0180	.0192
.0414	.0536	.0435	.0345	.0287	.0203	.0163
.0340	.0435	.0449	.0328	.0276	.0206	.0175
.0260	.0345	.0328	.0321	.0259	.2010	.0135
.0250	.0287	.0276	.0259	.0267	.0208	.0179
.0180	.0203	.0206	.0210	.0208	.0262	.0222
.0192	.0163	.0175	.0135	.0179	.0222	.0453

Group 2 (LD)						
.0725	.0579	.0403	.0288	.0117	-.0047	-.0101
.0579	.0515	.0350	.0244	.0088	-.0058	-.0087
.0403	.0350	.0311	.0213	.0054	-.0050	-.0026
.0288	.0244	.0213	.0191	.0052	-.0049	-.0057
.0117	.0088	.0054	.0052	.0057	-.0023	.0101
-.0047	-.0058	-.0050	-.0049	.0023	.0115	.0090
-.0101	-.0087	-.0026	-.0057	.0101	.0090	.0324

Variance-covariance matrices for hypothesis two

Group 1 (normal)						
.0692	.0551	.0389	.0328	.0253	.0289	.0290
.0551	.0600	.0410	.0356	.0279	.0309	.0267
.0389	.0410	.0415	.0328	.0245	.0198	.0216
.0328	.0356	.0328	.0400	.0316	.0229	.0181
.0253	.0275	.0245	.0316	.0355	.0259	.0268
.0289	.0309	.0198	.0229	.0259	.0345	.0242
.0290	.0267	.0216	.0181	.0208	.0242	.0427

Group 2 (LD)						
.0792	.0633	.0427	.0404	.0157	-.0003	-.0053
.0633	.0575	.0398	.0349	.0121	-.0125	-.0094
.0427	.0398	.0320	.0268	.0099	-.0015	-.0056
.0404	.0349	.0268	.0285	.0121	.0024	-.0030
.0157	.0121	.0099	.0121	.0116	.0083	.0067
-.0003	-.0025	-.0015	.0024	.0083	.0203	.0232
-.0053	-.0094	-.0056	-.0030	.0067	.0232	.0417

Variance-covariance matrices for hypothesis three

Group 1 (normal)						
.0447	.0346	.0283	.0235	.0270	.0198	.0194
.0346	.0427	.0346	.0298	.0326	.0274	.0208
.0283	.0346	.0381	.0280	.0323	.0283	.0236
.0235	.0298	.0280	.0292	.0285	.0250	.0205
.0270	.0326	.0323	.0285	.0383	.0306	.0246
.0198	.0274	.0283	.0250	.0306	.0360	.0281
.0194	.0208	.0236	.0205	.0246	.0281	.0364

Group 2 (LD)						
.0630	.0529	.0345	.0214	.0158	.0087	.0022
.0529	.0568	.0375	.0244	.0197	.0119	.0054
.0345	.0375	.0316	.0179	.0135	.0086	.0035
.0214	.0244	.0179	.0151	.0083	.0059	.0010
.0158	.0197	.0135	.0083	.0151	.0112	.0046
.0087	.0119	.0086	.0059	.0112	.0190	.0117
.0022	.0054	.0035	.0010	.0046	.0117	.0188

Variance-covariance matrices for hypothesis four

Group 1 (normal)						
.0450	.0347	.0353	.0280	.0255	.0227	.0179
.0347	.0398	.0370	.0312	.0270	.0218	.0194
.0353	.0370	.0468	.0318	.0330	.0261	.0195
.0280	.0312	.0318	.0405	.0346	.0255	.0230
.0255	.0270	.0330	.0346	.0406	.0312	.0225
.0227	.0218	.0261	.0255	.0312	.0302	.0219
.0179	.0194	.0195	.0230	.0225	.0219	.0311

Group 2 (LD)						
.0560	.0458	.0350	.0258	.0191	.0123	.0001
.0458	.0477	.0384	.0269	.0177	.0108	-.0002
.0350	.0384	.0344	.0245	.0137	.0069	-.0026
.0258	.0269	.0245	.0216	.0098	.0052	-.0020
.0191	.0177	.0137	.0098	.0116	.0089	.0049
.0123	.0108	.0069	.0052	.0089	.0141	.0130
.0001	-.0602	-.0026	-.0020	.0049	.0130	.0269

APPENDIX B

Variance-covariance Matrices for Posttest Analyses

Variance-covariance matrices for hypothesis six

Chunking Group (a_1)						
.0492	.0241	.0168	.0166	.0047	-.0054	-.0008
.0241	.0243	.0143	.0135	.0068	.0026	-.0003
.0168	.0143	.0111	.0089	.0041	-.0008	.0011
.0166	.0135	.0089	.0116	.0023	.0025	-.0026
.0047	.0068	.0041	.0023	.0079	.0037	.0040
-.0054	.0026	-.0008	.0025	.0037	.0109	.0003
-.0008	-.0003	.0011	-.0026	.0040	.0003	.0164

Verbal Stringing (a_2)						
.0458	.0285	.0260	.0102	.0202	.0229	.0288
.0285	.0223	.0157	.0047	.0095	.0129	.0109
.0260	.0157	.0346	.0142	.0200	.0252	.0310
.0102	.0047	.0142	.0186	.0220	.0169	.0198
.0202	.0095	.0200	.0220	.0323	.0275	.0300
.0229	.0129	.0252	.0169	.0275	.0311	.0293
.0288	.0109	.0310	.0198	.0300	.0293	.0521

Hawthorne Group (a_3)						
.0198	.0079	.0044	.0000	.0019	.0061	.0179
.0079	.0118	.0063	.0077	.0045	.0066	.0025
.0044	.0063	.0078	.0055	.0023	.0064	-.0041
.0000	.0077	.0055	.0131	.0054	.0059	-.0053
.0019	.0045	.0023	.0054	.0050	.0054	.0038
.0061	.0066	.0064	.0059	.0054	.0144	.0053
.0179	.0025	-.0041	-.0053	.0038	.0053	.0367

Variance-covariance matrices for hypothesis eight

Chunking Group (a_1)						
.0416	.0356	.0201	.0012	-.0086	-.0105	.0041
.0356	.0445	.0251	.0097	-.0053	-.0031	.0072
.0201	.0251	.0204	.0076	-.0026	-.0077	-.0003
.0012	.0097	.0076	.0082	.0007	-.0008	-.0019
-.0086	-.0053	-.0026	.0007	.0110	.0084	.0068
-.0105	-.0031	-.0077	-.0008	.0084	.0220	.0191
.0041	.0072	-.0003	-.0019	.0068	.0191	.0430

Verbal Stringing Group (a_2)						
.0351	.0223	.0149	.0142	.0089	.0205	.0126
.0223	.0248	.0164	.0136	.0101	.0178	.0176
.0149	.0164	.0266	.0152	.0073	.0113	.0137
.0142	.0136	.0152	.0201	.0177	.0242	.0214
.0089	.0101	.0073	.0177	.0217	.0247	.0204
.0205	.0178	.0113	.0242	.0247	.0498	.0432
.0126	.0176	.0137	.0214	.0207	.0432	.0511

Hawthorne Group (a_3)						
.0281	.0140	.0147	.0132	.0001	-.0072	-.0163
.0140	.0217	.0166	.0086	.0006	-.0084	-.0166
.0147	.0166	.0205	.0208	.0038	.0027	-.0172
.0132	.0086	.0208	.0463	.0120	.0164	-.0102
.0001	.0006	.0038	.0120	.0107	.0135	.0129
-.0072	-.0084	.0027	.0164	.0137	.0304	.0232
-.0163	-.0166	-.0172	-.0102	.0129	.0232	.0490

Variance-covariance matrices for hypothesis ten

Chunking Group (a_1)

.0786	.0501	.0136	.0054	.0220	.0102	.0152
.0501	.0578	.0231	.0126	.0142	-.0090	.0005
.0136	.0231	.0288	.0226	.0118	-.0007	.0082
.0054	.0126	.0226	.0240	.0100	.0104	.0158
.0220	.0142	.0118	.0100	.0180	.0105	.0124
.0102	-.0090	-.0007	.0104	.0105	.0476	.0355
.0152	.0005	.0082	.0158	.0124	.0355	.0309

Verbal Stringing Group (a_2)

.0583	.0595	.0312	.0088	.0058	.0118	.0216
.0595	.0727	.0373	.0092	.0116	.0072	.0145
.0312	.0373	.0217	.0048	.0012	.0024	.0074
.0088	.0092	.0048	.0067	.0043	.0016	.0062
.0058	.0116	.0012	.0043	.0272	.0074	.0095
.0118	.0072	.0024	.0016	.0074	.0124	.0154
.0216	.0145	.0074	.0062	.0095	.0154	.0317

Hawthorne Group (a_3)

.0396	.0203	.0111	-.0008	.0073	.0064	-.0075
.0203	.0155	.0078	.0011	.0046	-.0015	-.0089
.0111	.0078	.0068	.0017	.0047	-.0046	-.0042
-.0008	.0011	.0017	.0027	.0031	-.0008	.0006
.0073	.0046	.0047	.0031	.0101	.0035	.0015
.0014	-.0015	-.0046	-.0008	.0035	.0265	.0140
-.0075	-.0089	-.0042	.0006	.0015	.0140	.0209

Variance-covariance matrices for hypothesis twelve

Chunking Group (a_1)

.0430	.0241	.0248	.0294	.0276	.0256	.0319
.0241	.0378	.0377	.0361	.0257	.0175	.0187
.0248	.0377	.0394	.0371	.0290	.0229	.0241
.0294	.0364	.0371	.0437	.0259	.0233	.0224
.0276	.0257	.0290	.0259	.0339	.0274	.0346
.0256	.0175	.0229	.0233	.0274	.0328	.0341
.0319	.0182	.0241	.0224	.0346	.0341	.0484

Verbal Stringing Group (a_2)

.0239	.0078	.0056	.0094	.0008	-.0055	-.0136
.0078	.0088	.0111	.0082	.0015	-.0023	-.0030
.0056	.0111	.0339	.0206	.0113	.0039	-.0043
.0094	.0082	.0206	.0349	.0164	-.0026	-.0041
.0008	.0015	.0113	.0164	.0107	-.0005	-.0010
-.0055	-.0023	.0039	-.0026	-.0005	.0118	.0095
-.0136	-.0030	-.0043	-.0041	-.0010	.0095	.0227

Hawthorne Group (a_3)

.0379	.0192	.0185	.0203	.0054	-.0111	-.0074
.0192	.0300	.0301	.0231	.0153	.0015	-.0054
.0185	.0301	.0389	.0343	.0146	-.0072	-.0117
.0203	.0231	.0343	.0375	.0129	-.0165	-.0161
.0054	.0158	.0146	.0129	.0156	.0062	.0012
-.0111	.0015	-.0072	-.0165	.0062	.0327	.0263
-.0074	-.0054	-.0117	-.0161	.0012	.0263	.0259

Funded under Public Law 91-230, Title
VI, Part E, Sections 641 and 642
Bureau of Education for the Handicapped
U. S. Office of Education